INFANT TRANSFER OF LEARNING ACROSS 2D/3D DIMENSIONS:
A TOUCH SCREEN PARADIGM

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Learning from television and touch screens is one specific kind of transfer of learning. In this context, transfer involves relating information between a 2-dimensional (2D) and 3-dimensional (3D) source. Prior research has shown that infants exhibit a transfer deficit, that is, they learn less from 2D sources in comparison to learning from face-to-face interactions with real objects. Researchers examining this deficit have traditionally used television to present 2D stimuli then assessed infants’ transfer of learning with corresponding 3D objects. For this dissertation, a touch screen was used to examine infants’ ability to transfer actions in a new direction – from 3D to 2D – as well as from 2D to 3D as in prior studies. Experiments 1 and 2 combine touch screen technology with the imitation paradigm. The aim of Experiment 1 was to establish the touch screen task as a viable method for examining imitation from 2D and 3D surfaces and across transfer (2D to 3D and 3D to 2D) dimensions. Infants produced significantly fewer target actions in the transfer dimension conditions compared to their within-dimension condition (2D to 2D or 3D to 3D) performance. Based on Hayne’s (2006) representational flexibility account, the aim of Experiment 2 was to increase the number of available retrieval cues by adding verbal labels during encoding and retrieval in the transfer conditions used in Experiment 1. Language cues did not augment infant imitation scores to above original transfer performance levels. In a third study, the touch screen task was adapted into a semi-naturalistic teaching task to examine the role of maternal teaching and the context in which transfer of learning between 2D and 3D
occurs. Infant transfer performance substantially increased compared to infant transfer performance in Experiments 1 and 2. Level of scaffolding was the only significant predictor of infant transfer success. Taken together, the results from this dissertation demonstrate that transfer of learning between 3D and 2D is cognitively challenging for infants. Infants’ representational system is fragile and can be easily overloaded; however infant transfer of learning can be improved through maternal scaffolding.
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# TABLE OF CONTENTS

**CHAPTER I: INTRODUCTION**………………………………………………………………… 1

References........................................................................................................................................ 8

**CHAPTER II: INFANT IMITATION FROM TELEVISION USING NOVEL TOUCH SCREEN TECHNOLOGY**………………………………………………………………… 13

Abstract........................................................................................................................................ 13

Introduction..................................................................................................................................... 14

Method.......................................................................................................................................... 22

Results.......................................................................................................................................... 27

Discussion..................................................................................................................................... 28

References..................................................................................................................................... 32

**CHAPTER III: VERBAL CUES DO NOT FACILITATE 15-MONTH-OLDS’ TRANSFER OF LEARNING ACROSS 2D/3D**…………………………………………………………………. 39

Abstract........................................................................................................................................ 39

Introduction..................................................................................................................................... 40

Method.......................................................................................................................................... 44

Results.......................................................................................................................................... 47

Discussion..................................................................................................................................... 49

References..................................................................................................................................... 53

**CHAPTER IV: MOTHERS ENHANCE INFANTS’ 2D-3D TRANSFER OF LEARNING: THE ROLE OF EMOTIONAL RESPONSIVENESS & MATERNAL STRUCTURING**……… 57

Abstract........................................................................................................................................ 57

Introduction..................................................................................................................................... 58
LIST OF FIGURES

CHAPTER II

Figure 1. Button box stimuli used in Experiments 1 and 2................................................. 24
Figure 2. Sample photograph of imitation of the target action on the 2D touch screen image.... 25
Figure 3. The mean imitation score of infants as a function of experimental condition.......... 28

CHAPTER IV

Figure 1. Experimental set-up for the touch screen teaching task...................................... 73
LIST OF TABLES

CHAPTER II

Table 1. Experimental demonstration and test groups....................................................... 23

CHAPTER III

Table 1. Nonsense label phrases provided during the demonstration and test phases for the
transfer (2D/3D, 3D/2D) conditions.................................................................................. 46

CHAPTER IV

Table 1. Mean demographic characteristics for infants by transfer success............... 86
Table 2. Proportion of mothers’ verbal teaching strategies used during the first and second
minute of the task........................................................................................................ 91
Table 3. First order correlations between proportions of mother verbal matching strategy use,
and maternal pointing.................................................................................................. 93
Table 4. Rate of maternal pointing per minute for infants who successfully transferred and
infants who did not successfully transfer................................................................... 94
Table 5. First order correlations between the frequency of infant vocalizations and infant
pointing............................................................................................................................ 96
Table 6. Rate of infant pointing per minute for infants who successfully transferred and
infants who did not successfully transfer................................................................... 97
Table 7. Minute-by-minute breakdown of latency to infant success from the start of the
session and from infants’ first touch of the test stimulus........................................... 99
Table 8. First order correlations between maternal pointing and infant pointing.............. 101
Table 9. Rate of maternal and infant button pushes by condition.................................... 103
Table 10. First order correlations between mother and infant latency to touch the 3D object and 2D image

Table 11. Mother and infant latency (seconds) to touch 3D object and 2D image by condition

Table 12. Mean emotional responsiveness ratings by infant transfer success

Table 13. Chi-square analyses for maternal structuring by infant transfer success

Table 14. First order correlations between maternal structuring, emotional responsiveness and infant activity level variables

Table 15. Maternal structuring, proportion of new maternal verbal input and overall emotional responsiveness as a function of scaffolding level

Table 16. Results from logistic regression analysis of infant transfer success

Table 17. Classification table for logistic regression on infant transfer success

Table 18. Factors that predict infant latency to transfer success
CHAPTER I: INTRODUCTION

Transfer of learning is an adaptive skill that develops gradually during early childhood. The ability to transfer information across content and context is important for day-to-day functioning. It is also central to memory theories, specifically the development of a flexible representational system (Barnett & Ceci, 2002; Hayne, 2006). Developmental studies on transfer of learning across physical contexts and objects have shown age-related changes in generalization using operant conditioning procedures and the imitation paradigm during early infancy (Barnat, Klein, & Meltzoff, 1996; Hanna & Meltzoff, 1993; Hayne, Boniface, & Barr, 2000; Hayne, Herbert, & Simcock, 2003; Hayne, MacDonald, & Barr, 1997; Herbert & Hayne, 2000; Klein & Meltzoff, 1999).

Learning from television and touch screens is one specific kind of transfer of learning. In this context, transfer involves relating information between a 2-dimensional (2D) and 3-dimensional (3D) source. Most adults effortlessly relate information between 2D and 3D sources, for example, using ingredients to prepare a real meal after watching a cooking show on television. However, this type of transfer between 2D and 3D presents a significant challenge for young children (Barr & Hayne, 1999; Barr, Muentener, & Garcia, 2007; Barr, Muentener, Garcia, Fujimoto, & Chavez, 2007; Hayne et al., 2003; Meltzoff, 1988).

Touch screens are not a tool traditionally used in research to examine transfer of learning. There are, however, both practical and methodological implications of examining touch screens. Touch screens are now ubiquitous in society, advancing our daily interactions through their incorporation into communication and entertainment devices such as phones, computers, and game consoles. Research has also shown that touch screens have potential to enhance learning in preschoolers (Wood et al., 1981) and to aid learning in children with mental and physical
handicaps (Howe, 1984). Touch screens have been used to study learning and memory in infants & preschoolers (Ayoun, 1998; Gerhardstein & Rovee-Collier, 2002; Sutton, 2006), and comparative imitation studies have been conducted with rhesus monkeys (Subiaul, Cantlon, Holloway, & Terrace, 2004; Subiaul, Cantlon, Romansky, Klein, & Terrace, 2007).

For the present line of research, use of a touch screen offers methodological advances from previous research on transfer of learning between 2D and 3D. Touch screens enable us to ask children to transfer actions in a new direction – from 3D to 2D – as well as testing transfer from 2D to 3D as in prior studies. This is an important avenue of research to pursue for a number of reasons.

First, screen media is increasingly present in the daily lives of young children. By 2 years of age, infants spend approximately one to two hours engaged with different types of screen media (Rideout & Hamel, 2006). However, there is little research illustrating how or what young children transfer from media sources to objects in the real world (for review, see Courage & Setliff, 2009).

Second, learning from 2D sources is cognitively challenging for young children. Studies have shown that infants learn less from 2D sources in comparison to learning from face-to-face interactions with real objects (e.g., Barr & Hayne, 1999; Barr, Muentener, & Garcia, 2007; Hayne et al., 2003; Meltzoff, 1988). This transfer deficit has been termed the video deficit effect. The video deficit is widely documented by many research groups using different tasks; these include imitation from television (Barr & Hayne, 1999; Barr, Muentener, & Garcia, 2007; Barr, Shuck, Salerno, Atkinson, & Linebarger, 2010; Dickerson, Zack, Barr, & Gerhardstein, 2010; Hayne et al., 2003; McCall, Parke, & Kavanaugh, 1977; McGuigan, Whiten, Flynn, & Horner, 2007; Meltzoff, 1988; Nielsen, Simcock, & Jenkins, 2008; Sheffield & Hudson, 2006) as well as
object search tasks (Deocampo & Hudson, 2005; Schmitt & Anderson, 2002; Suddendorf, 2003; Troseth, 2003; Troseth & DeLoache, 1998), emotion processing tasks (Mumme & Fernald, 2003) and language based tasks (Kuhl, Tsao, & Liu, 2003). It is not present at 6 months, peaks around 15 months and persists until at least 3 years of age depending on task complexity (e.g., Barr & Hayne, 1999; Barr, Muentener & Garcia, 2007; Dickerson et al., 2010; Flynn & Whiten, 2008). Although the video deficit is a widely documented effect, there is no coherent theory to explain the findings.

In previous studies examining imitation from television, children were required to observe a demonstration on a 2D source and then reproduce the target actions on a 3D object. That is, the infants encode a representation of the action from a 2D input and then retrieve a memory of the action in the presence of a 3D object. Such a design does not allow determination of why the video deficit occurs. There have been a number of potential explanations proposed to explain the deficit: (a) perceptual impoverishment of the 2D stimulus; (b) poor symbolic representation; (c) poor representational flexibility due to the cognitive load involved in transferring information from a 2D demonstration to a 3D object; or (d) from a combination of these factors. Each of these possibilities will be addressed in Chapter II. The present studies were conceptualized within the broader framework of Karmiloff-Smith’s (1992) representational redescription model (RR Model) and more specifically, Hayne’s (2006) account of the development of representational flexibility.

Karmiloff-Smith’s (1992) RR Model was developed to gain an understanding of how children acquire language and complete complex spatial tasks; however its basic premise can also be applied to transfer of learning. The RR model proposes that children’s representations change and are re-represented in different formats as knowledge is gained through new
experiences across development. For example, a representation that is initially stored in a perceptual format might be re-represented in a linguistic format; through redescription the two become interrelated over time. It is through this process that representations become more flexible. Thus, for transfer of learning, infants’ representation of the 3D object and 2D image may not initially be stored in an interrelated format.

Hayne’s account on the development of representational flexibility also proposes that children become more flexible in their representations across development. Hayne’s account specifically addresses the deficit in 2D-3D transfer from media, providing one potential explanation for the deficit in infant’s transfer of learning (Hayne, 2006). Hayne (2006) argues that early in development, successful memory performance is dependent on an exact match of cues; any mismatch in the nature of the object or image present at learning and at test can disrupt memory performance. Success on 2D-3D transfer tasks would depend on a flexible capacity to recognize and act on the stimulus regardless of its dimension at the time of encoding.

The representational flexibility account posits the existence of an active developmental process whereby performance is dependent upon age, task, and experience. Over time, infants learn to encode information in a variety of contexts and to take advantage of a wide range of retrieval cues. Based on Hayne’s theoretical account, it is more challenging to relate information between 2D and 3D than within the same dimension (e.g., 2D to 2D or 3D to 3D) because there are fewer retrieval cues at test that match encoding conditions (Hayne, 2006).

Each study in this dissertation tests Hayne’s representational flexibility theoretical assumptions that difficulty transferring learning across dimension is due to lack of effective retrieval cues at the time of test. More specifically, this will be tested by first examining infants’ 2D-3D transfer of learning, establishing the touch screen imitation paradigm (Chapter II), then
by adding language retrieval (Chapter III) and social (Chapter IV) cues. The dissertation studies employ a novel approach, using touch screen technology to examine 15-month-olds’ transfer of learning from 3D to 2D (as well as 2D to 3D as before) using experimental (Chapters II and III) and semi-naturalistic tasks (Chapter IV).

For the experimental studies, an imitation approach was used in combination with the touch screen. The imitation paradigm is a robust method for investigating the video deficit effect. In this paradigm, infants observe an experimenter demonstrating a novel action, usually several times in succession. Then, infants are given the opportunity to reproduce the action with the objects either immediately or after a specified delay (Meltzoff, 1988, 1995). Infants’ performance is compared to that of an age-matched control group who never saw the demonstration – the performance of these infants is used to determine the rate of spontaneous production of the target actions. Meltzoff’s (1988) study examining imitation from television in 14- and 24-month-olds documented that infants could in fact imitate from television; the video deficit effect is based on the fact that infants’ imitation from 2D sources are not as proficient as their imitation from real-world objects.

The primary aim of Experiment 1 was to establish the touch screen task as a viable method for examining imitation from 2D and 3D surfaces and across transfer (2D to 3D and 3D to 2D) dimensions. More specifically, the aims were to (a) establish the baseline rate of button pushing for the 2D touch screen images and 3D objects; (b) to determine whether infants would imitate the target actions on the 2D touch screen and the 3D object; and (c) to test whether infants would show transfer of learning.

Based on Hayne’s (2006) representational flexibility account, the aim of Experiment 2 (Chapter III) was to increase the number of available retrieval cues by adding verbal labels
during encoding and retrieval in the transfer conditions of the touch screen task. Prior research has shown that labeling facilitates categorization, imitation, and generalization in infants as young as 9 months (e.g., Booth & Waxman, 2002; Herbert, 2008; Lukowski, Wieber, & Bauer, 2009) and facilitates transfer of learning from picture books to the real world in infants as young as 15 months old (Ganea, Bloom Pickard, & DeLoache, 2008). Thus, it was hypothesized that the addition of a shared verbal label would augment infants’ transfer performance by highlighting that the image and the object are from the same object category.

In a third study (Chapter IV), the touch screen imitation task was transformed into a semi-naturalistic teaching task to examine the context in which transfer of learning between 2D and 3D occurs. There were 3 primary aims to this study: 1) to examine infants’ ability to transfer learning between 2D and 3D in the context of a novel teaching situation; 2) to describe mothers’ semi-naturalistic teaching of 2D to 3D information transfer; and 3) to examine what maternal and infant factors contribute to transfer of learning between 2D and 3D.

Research on parent-child interactions and teaching tasks, as well as Bandura (1977, 1986) and Vygotsky’s (1978) theory on the role of social interaction in learning suggest that high quality interactions between infants and caregivers should provide a scaffold under challenging learning conditions. Prior research also suggests that the presence of a sensitive and responsive social partner may have important influences on infants’ learning from 2D sources (Fidler, Zack, & Barr, 2010). Therefore caregiver scaffolding may play a vital role in infants’ transfer of learning between 2D and 3D.

There were two primary measures that were used to examine maternal teaching and interactions within the mother-infant dyad during the touch screen transfer of learning task: maternal verbal input and emotional responsiveness/structuring. The emotional responsiveness
and structuring measures encompass both mother and infant behaviors, such as amount of turn taking and shared focus during the task.

Infants’ ability to transfer information between 2D media sources and the real world is still a relatively unexplored field. By examining transfer of learning from 3D to 2D as well as from 2D to 3D in experimental and semi-naturalistic tasks, this dissertation work adds to the emerging literature on infant learning and memory from 2D sources and the role of maternal scaffolding in a media context. Examining transfer of learning from 2D media will also shed further light on infants’ emerging representational system. Taken together, the results from the three studies presented in this dissertation will advance our understanding of factors involved in transfer of learning in the digital age and will have important practical implications for how best to design and use media as an effective teaching tool.
References


CHAPTER II: INFANT IMITATION FROM TELEVISION USING NOVEL TOUCH SCREEN TECHNOLOGY


**Abstract**

Infants learn less from a televised demonstration than from a live demonstration, the video deficit effect. The present study employs a novel approach, using touch screen technology to examine 15-month olds’ transfer of learning. Infants were randomly assigned either to within-dimension (2D/2D or 3D/3D) or cross-dimension (3D/2D or 2D/3D) conditions. For the within-dimension conditions, an experimenter demonstrated an action by pushing a virtual button on a 2D screen or a real button on a 3D object. Infants were then given the opportunity to imitate using the same screen or object. For the 3D/2D condition, an experimenter demonstrated the action on the 3D object, and infants were given the opportunity to reproduce the action on a 2D touch screen (and vice versa for the 2D/3D condition). Infants produced significantly fewer target actions in the cross-dimension conditions than in the within-dimension conditions. These findings have important implications for infants’ understanding and learning from 2D images and for their using 2D media as the basis of actions in the real world.
Introduction

Early screen media exposure has come to the forefront of public health debate as parents increasingly use computers, television, and interactive books and games as teaching tools with infants in the first year of life (Rideout & Hamel, 2006; Zimmerman, Christakis, & Meltzoff, 2007). Over the past 15 years, the media landscape for infants has changed dramatically. During the 1990’s, television programs such as Teletubbies and videos/DVDs such as Baby Einstein started to be produced specifically for infants. In a typical infant-directed video, images of everyday objects, toys, and puppets are shown set to music without narration or a storyline. Sales estimates of infant media products were $100 million dollars annually in the US in 2004 (Garrison & Christakis, 2005) and some estimates put them as high as $200 million today. Most recently V-smile and Leapfrog have started producing educational videogames and interactive books that use touchpads for children 3 years and younger.

In some cases, infant videos/DVDs and TV programs are marketed in a way that leads parents to believe their babies will engage in important learning from them (Garrison & Christakis, 2005). Parents believe that there are beneficial effects of very early exposure to television and computers (Calvert, Rideout, Woolard, Barr, & Strouse, 2005). For example, in a 2006 survey of 1000 US families with children between 2 and 24 months old, the leading justification parents gave for fostering infant video/DVD viewing was that such media “teach him/her something or are good for his/her brain” (Zimmerman et al., 2007). Nonetheless, whether and how infants and toddlers learn from 2D sources and transfer information so that it can be used to control action in the real world has not received sufficient empirical attention (see Anderson & Pempek, 2005). This study is the first that we know of to experimentally examine
transfer of learning from an interactive touch screen interface to real world objects during infancy.

**Video-Deficit Effect**

Empirical research conducted using a number of different experimental paradigms has demonstrated that infants, toddlers, and preschool children learn less from television and 2D still images than from live face-to-face interactions (Anderson & Pempek, 2005; Barr & Hayne, 1999; Barr, Muentener, & Garcia, 2007a; Barr, Muentener, Garcia, Fujimoto, & Chavez, 2007b; DeLoache & Burns, 1994; Deocampo & Hudson, 2005; Grela, Krcmar, & Lin, 2004; Hayne, Herbert, & Simcock, 2003; Hudson & Sheffield, 1999; Kuhl, Tsao, & Liu, 2003; McCall, Parke, & Kavanaugh, 1977; Mumme & Fernald, 2003; Schmitt & Anderson, 2002; Sell, Ray, & Lovelace, 1995; Sheffield & Hudson, 2006; Simcock & DeLoache, 2006; Suddendorf, Simcock, & Nielsen, 2007; Troseth, 2003; Troseth & DeLoache, 1998). This has been termed the *video deficit effect*: Infants’ ability to transfer learning from television to real-life situations is relatively poor (Anderson & Pempek, 2005) compared to their impressive transfer of learning from a live demonstration to a different situation (Anderson & Pempek, 2005; Klein & Meltzoff, 1999). In the case of imitation studies, beginning around 6 to 14 months of age, infants can imitate limited actions demonstrated by videotaped models (Barr et al., 2007a; Meltzoff, 1988a). The video deficit for imitating from 2D displays has been reported to peak around 15 months and persist until 30 months (Barr & Hayne, 1999; Barr et al., 2007a,b; Hayne et al., 2003; McCall et al., 1977).

In most previous studies examining imitation from television, children were required to observe a demonstration on a 2D source and then reproduce the target actions on a 3D object. That is, the infants encode a representation of the action from a 2D input and then successfully
retrieve a memory of the action in the presence of a 3D object. Such a design does not allow
determination of whether the reported video deficit effect arises from: (a) perceptual
impoverishment of the 2D stimulus; (b) poor understanding of the 2D array (e.g., due to an
inability to appreciate the dual nature of symbols); (c) poor representational flexibility due to the
cognitive load involved in transferring information from a 2D demonstration to a 3D object; or
(d) from a combination of these factors.

**Perceptual encoding impoverishment.** Mapping a memory encoded from a 2D image
onto a 3D object presented at a later time, and used for the basis of action, relies on a
representation of the object that can enable translation between dimensions. The need for a
translation between images and objects presents significant challenges. Two-dimensional images
may be difficult for toddlers to understand for a number of perceptual reasons: In most
laboratory tests, they are smaller in size than the real objects, the resolution of the image is
degraded relative to real objects, and many aspects of the object (depth cues from self-induced
motion, shadow, and gradients, for example) are at best absent, and at worst substantially
different, across the 3D-2D change. Even color values are likely to change to some degree when
a TV image replaces a 3D object.

This impoverished presentation may have substantial implications for visual processing.
Two recent studies suggest that 2D information is processed differently than 3D information
during infancy. First, researchers using event-related potentials (ERPs) have demonstrated that
18-month-olds process 2D images more slowly than 3D objects, recognizing a familiar 3D object
very early in the attention process (shown by the early sensory exogenous N2 component) and
recognizing a 2D digital photo of the familiar object significantly later (during the middle latency
Nc component) (Carver, Meltzoff, & Dawson, 2006). Second, researchers using NIRS (near-
infrared spectroscopy) have demonstrated that 6-month-olds actively process live demonstrations of action in the sensorimotor cortex more than when the same information is presented on television (Shimada & Hiraki, 2006). It is possible that this difference is preserved throughout life (see Bennett & Vuong, 2006; Wang & Kameda, 2005).

**Poor understanding of 2D symbols and dual representations.** DeLoache and colleagues (DeLoache, 1995; DeLoache, Kolstad, & Anderson, 1991; Pierroutsakos & DeLoache, 2003; Troseth, Pierroutsakos, & DeLoache, 2004) have proposed a *dual representation hypothesis* to account for the video deficit effect. They argue that children’s difficulty relating 2D depictions (moving or stationary) to the real world is due to young children’s immature understanding of symbolic artifacts such as pictures and television. Early in development, toddlers do not understand the dual nature of symbols. That is, toddlers do not comprehend that a symbol is both an object in itself (e.g., a television set) as well as a representation of another entity (e.g., the depiction on the monitor).

One important developmental step in learning from television and computers is appreciating both the similarities and the differences between 2D and 3D stimuli and being able to act accordingly (Flavell, Flavell, Green, & Korfmacher, 1990; Rose, 1977; Troseth et al., 2004). That this ability develops is buttressed by published reports that in the first year of life, infants sometimes treat objects on television as if they have 3D properties. They have been observed to manually explore 2D images and try to grasp them in ways that are reminiscent of how they interact with 3D objects (Flavell et al., 1990; Lemish, 1987; Pierroutsakos & DeLoache, 2003; Pierroutsakos & Troseth, 2003). According to this account, it is during the 2nd year of life that infants more sharply differentiate 2D images and 3D objects and learning from television decreases (the video deficit effect). This decrease in learning suggests that the
developmental course of this ability does not result from a simple linear increase in perceptual capacity.

DeLoache (1991) argues that not until toddlers have sufficient experience with a range of symbols do they begin to understand their representational power and thus begin to relate them to the real world in an adult-like way. Two-year-olds fail to apply information presented on television to real world situations (Troseth, Saylor, & Archer, 2006; Troseth & DeLoache, 1998). Thus, the informational value of actions presented in 2D (on video) is substantially diminished because children do not recognize the functional significance of the objects and actions they view on the screen. According to this view, it is not until almost the 3rd year of life that children come to understand that video can provide meaningful information to guide actions in the real world, and the video deficit effect disappears.

**Poor representational flexibility.** Although the perceptual impoverishment and dual representation accounts differ in their explanations of the video deficit, they both agree that the very nature of the media makes it difficult for toddlers to understand and relate to corresponding real-world objects. The representational flexibility account emphasizes a different type of difficulty presented by the need to equate between television (and other 2D media) and 3D objects. According to this account, the challenge is that the toddler must cognitively match a 2D symbol present at encoding to the corresponding 3D referent present at testing. Memory theorists generally assume that a memory is a hypothetical collection of attributes that represent what the subject noticed at the time of original encoding (Estes, 1973, 1976; Roediger, 2000; Spear, 1978; Tulving, 1983; Underwood, 1969). The encoding specificity hypothesis states that a memory will be retrieved only if an individual encounters a cue with attributes that match those represented in the memory at the time of original encoding (Tulving, 1983). The ability to retrieve memories
despite changes in proximal or distal cues to allow learning to be generalized to novel situations has been referred to as ‘representational flexibility’ (Eichenbaum, 1997).

Hayne (2004) argues that there are marked developmental changes in representational flexibility in infancy. That is, early in development, successful memory performance is dependent on the perception of a close match between the cues at the time of encoding and the cues at retrieval; even minor mismatch at testing can disrupt performance. Of course, this process depends upon a match or mismatch being detected. During the first year of life infants may be matching the surface features (and not basing their actions on the discrepancy between 2D and 3D objects—see the dual representation hypothesis above for a similar argument). Thus the onset of the video deficit occurs during the second year of life when a mismatch is detected. However, subsequent to the onset of this effect, memory performance becomes more flexible with age and older participants show an increased ability to tolerate differences between conditions at encoding and retrieval and can use novel cues to retrieve a target memory. This has been supported empirically with infants showing excellent generalization using operant conditioning procedures (Hartshorn et al., 1998; Hayne & Findlay, 1995; Hayne, Rovee-Collier, & Perris, 1987) and with toddlers using the imitation paradigm (Barnat, Klein, & Meltzoff, 1996; Hanna & Meltzoff, 1993; Hayne et al., 2003; Hayne, Boniface, & Barr, 2000; Hayne, MacDonald, & Barr, 1997; Herbert & Hayne, 2000; Klein & Meltzoff, 1999). Ultimately success on the transfer task would depend on the operation of a flexible capacity to recognize and act on the stimulus regardless of its dimension at the time of encoding.

The Imitation Paradigm

The imitation paradigm provides a powerful way of investigating the video deficit effect. Based on Piaget’s (1962) theoretical conceptualization, Meltzoff (1988b, 1988c, 1995)
introduced a deferred imitation paradigm that can be used in the laboratory with infants. In this paradigm, infants observe an experimenter demonstrating a novel action, usually several times in succession. Then, infants are given the opportunity to reproduce the action with the objects either immediately or after a specified delay. Their performance is compared to that of an age-matched control group who never saw the demonstration — the performance of these infants is used to determine the rate of spontaneous production of the target actions. There are key aspects of Meltzoff’s deferred imitation paradigm that make it a useful tool for studying high-level cognition in a preverbal population: (a) the participant is prevented from interacting with the objects prior to the test, which precludes motor learning; (b) the duration of the response phase is controlled; (c) imitative performance is compared to a no-model control group, which reduces the likelihood that the participant is guessing the target actions based on the appearance of the objects; and (d) the responses that count as imitative are rigorously defined and scored from videotape records by scorers who are blind to experimental condition.

**Imitation from television.** Meltzoff (1988a) adapted the imitation procedure to televised stimuli. He exposed infants to a televised model demonstrating a novel target action. He found that infants as young as 14 months of age reproduced a one-step action viewed on television above rates produced by age-matched controls who never viewed the target action. The study documented both immediate and deferred imitation (spanning a 24-hr delay). Successful deferred imitation from a videotaped model requires formation of both an object and an action representation that can be retained over a delay. At the time of the test, infants must match perceptual attributes of the 3D test object that is presented to the child to stored attributes of the memory representation of the original 2D video display. Meltzoff’s study was an ‘existence proof’ that infants could imitate from television; the video deficit effect is based on the fact that
infants are not as proficient at imitating from television as they are when imitating live, 3D models.

**The present study.** Prior imitation studies have used traditional television to present the 2D stimuli and then assessed infants’ performance with a 3D test object. It is possible that any decrement in performance as compared to live demonstrations is simply due to encoding from a degraded/impoverished 2D stimulus. One innovation of the current study is the use of touch screen technology that permits tests from 2D to 2D and from 3D to 2D (as well as testing from 2D to 3D as before). Combining the touch screen methodology with the imitation approach will contribute to the nascent literature examining learning and educational applications from 2D media during infancy, adding to our understanding of comprehension of media in very young and vulnerable populations (e.g., Barr et al., 2007a,b; Zimmerman et al., 2007; Troseth et al., 2006). Based on Hayne’s representational flexibility hypothesis, transferring information from 2D stimuli to 3D objects (and vice versa) would be more challenging than relating objects within the same dimension (i.e., 2D to 2D or 3D to 3D) because there are fewer retrieval cues at the time of the test that specifically match the original encoding conditions.

The present experiment examines imitation from 2D and 3D surfaces and transfer across dimensions. We sought to establish the feasibility of the combined imitation-touch screen methodology. We had the following specific aims: (a) to obtain the baseline rate of button pushing for the 2D touch screen and 3D objects, (b) to establish whether infants would imitate the target actions on the 2D touch screen and the 3D object, and (c) to test whether infants would imitate across dimension.
Method

Participants

Seventy-two 15- to 16-month-old (26 male, 46 female) full-term healthy infants and their parents were recruited through commercially available records, childcare centers, and by word of mouth in the DC metro (65.3% of data) and Binghamton metro (34.7% data) areas. Infants ranged in age from 431 days to 521 days ($M = 476.2$, $SD = 19.0$). Participants were African American ($n = 1$), Asian ($n = 1$), Caucasian ($n = 66$), mixed descent ($n = 3$) and unreported ($n = 1$). The Caucasian sample included one Latino participant. The majority of infants were from middle- to upper-class, highly educated families. Their parents’ mean educational attainment was 17.0 years ($SD = 1.45$) based on 93.6% of the sample, and their mean rank of socioeconomic status (Nakao & Treas, 1992) was 72.2 ($SD = 19.2$) based on 84.7% of the sample. Infants were randomly assigned to one of six experimental groups ($n=12$/group; see Table 1): 3D demo/3D test, 2D demo/2D test, 3D demo/2D test, 2D demo/3D test, 3D baseline control, and 2D baseline control. Additional infants were excluded from the final sample due to experimenter error or interference ($n = 3$), parental interference ($n = 1$), or failure to touch the stimuli during the test phase or failure to sit through demonstration ($n = 3$).
Table 1

Experimental demonstration and test groups

<table>
<thead>
<tr>
<th>Group</th>
<th>Demo</th>
<th>Experimenter action</th>
<th>Test</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Within-Dimension</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3D Demo/3D Test</td>
<td>Real object</td>
<td>Press button on 3D stimulus</td>
<td>Real object</td>
</tr>
<tr>
<td>2D Demo/2D Test</td>
<td>Touch screen</td>
<td>Press virtual button on 2D stimulus</td>
<td>Touch screen</td>
</tr>
<tr>
<td><strong>Cross-Dimension</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3D Demo/2D Test</td>
<td>Real object</td>
<td>Press button on 3D stimulus</td>
<td>Touch screen</td>
</tr>
<tr>
<td>2D Demo/3D Test</td>
<td>Touch screen</td>
<td>Press virtual button on 2D stimulus</td>
<td>Real object</td>
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<tr>
<td><strong>Baseline</strong></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>3D Baseline</td>
<td></td>
<td></td>
<td>Real object</td>
</tr>
<tr>
<td>2D Baseline</td>
<td></td>
<td></td>
<td>Touch screen</td>
</tr>
</tbody>
</table>

**Apparatus**

We adapted button boxes that had been developed by Meltzoff (1988a) for use in previous imitation studies. None of the completed stimulus objects was commercially available.

**3D stimuli.** Four novel objects were created from a black button box (16.5 wide x 15 tall x 5.5 cm) decorated with felt, art foam, pipe cleaners, stickers, cotton balls, and googly eyes to create a school bus, a fire truck, a cow, and a duck (see Figure 1). The two vehicles (bus and fire truck) have a slightly recessed rectangle-shaped button (2.2 x 3cm) on the right surface in the middle of the box (16.5 wide x 15 tall x 5.5 cm deep). The two animals (duck and cow) have a slightly recessed circular button (2.2 x 2.2 cm in diameter) on the left surface in the middle of the box (16.5 wide x 15 tall x 5.5 cm deep). Pressing the button activates a switch which produces a
different sound for each object: a horn honking (bus), a siren (fire truck), duck quacking, or cow mooing.

![Button boxes](image)

**Figure 1.** The button boxes (16.5 wide x 15 tall x 5.5 cm) have a recessed button that make the sound of a: (A) horn honking, (B) siren, (C) duck quacking or (D) cow mooing when pressed.

**2D stimuli & touch screen.** Digital photos were taken of each of the four previously described 3D objects and displayed on a 17 in. LCD touch screen (see Figure 2). The touch screen was connected to a laptop and programmed with the images of the 3D objects using software used in various touch screen tests of infants (e.g., Gerhardstein & Rovee-Collier, 2002). The button areas were programmed such that pressing the “virtual button” produced the same sound as pressing the actual button on the 3D object. The images were equated in size to the 3D object at approximately the same viewing distance.

**Experimental set-up.** A lap table (61 wide x 32 tall x 37.5 cm deep) was placed on the floor and used as the testing surface for all conditions. The 3D object or 2D touch screen was placed on the lap table, as shown in Figure 2. Children sat on a child size step stool or their caregiver’s lap. Every child saw one vehicle and one animal stimulus (e.g., truck/cow); stimulus and presentation order were counterbalanced within and between groups. Stimuli were covered and kept out of the infant’s sight when not in use.
Figure 2. Sample photograph of imitation of the target action on the 2D touch screen image.

Procedure

Infants were primarily visited in their homes; however a small subset of participants (n = 6) were tested in a childcare center. All participants were tested in a single session. An experimenter described the study to and obtained informed consent from the caregiver. Before the start of the session, caregivers were instructed not to name the object or the sound it makes, or to point out anything on the stimulus, including the button. Caregivers were permitted to respond to what their infant was interested in (e.g., you’re touching the eyes), to say neutral phrases (e.g., look at that) or to offer encouragement if the infant responded correctly (e.g., good job) during the test phase. A second experimenter videotaped the session from a side angle, such that both the infant and the object/touch screen were visible. All phases of the experiment were videotaped for later analysis.

Half of the infants were administered a within-dimension test (3D demo/3D test, 2D demo/2D test) and half were administered a cross-dimension test (2D demo/3D test, 3D demo/2D test). The 2D and 3D baseline control groups were used to assess the spontaneous
production of the target actions in the absence of the demonstration. Infants in these baseline control groups did not participate in the demonstration phase. Rather, they were shown the test stimuli for the first time during the test phase.

**Demonstration phase.** The session began with the infant seated approximately 3 feet away from the lap table. An experimenter knelt down next to the table on the side of the stimulus opposite the button/virtual button (e.g., the cow button is on the left side of the object/image so the experimenter knelt on the right side of the table). The experimenter demonstrated the target action six times in succession for the first stimulus by extending the index finger and reaching across the front of the stimulus (3D object or 2D image) to push the button/virtual button. The target actions were not verbally described, but to maintain the infants’ attention on the test stimuli, the experimenter used phrases such as, “Isn’t this fun?” speaking in a manner characteristic of “parentese.” Following the six demonstrations with the first stimulus, the stimulus was removed and the experimenter moved to the opposite side of the table and repeated the above procedure for the second stimulus. The demonstration period was fixed at approximately 30 s per stimulus ($M = 32.1$ s, $SD = 4.0$ for the 3D objects and $M = 33.8$ s, $SD = 7.0$ for the 2D touch screen images). Small variations in the demonstration times were due to occasional interruptions in the household, such as a phone ringing, technical problems on the touch screen, or infant fussiness. At the end of the demonstration phase, caregivers moved their infants forward so that they were seated at the table. There was a delay of less than 20 s between the demonstration and test phase, regardless of condition.

**Test phase.** The test phase was the same for all infants. During the test phase, the infant was seated at the lap table facing the toy/touch screen image. Infants were given 30 s from time of first touch of the toy or screen to imitate the target action on each stimulus. Stimuli were
presented in the same order as during the demonstration. Infants in the experimental groups were tested with the same animal and vehicle they viewed during the demonstration.

**Survey data on television exposure.** To estimate the amount of daily exposure to television by infants in our total sample, parents were asked how many hours per day their televisions were typically in use. This information was collected from 69.4% of parents. Parents reported that the television was on for an average of 2.6 hrs per day ($SD = 1.6$ hours). This is consistent with recent nationally representative sample data (e.g., Rideout & Hamel, 2006).

**Coding and Reliability**

A primary coder scored whether infants imitated the target action (pressing the button) during the test session from videotape (see Figure 2). For each test trial, an imitation score of “0” was given if the infant did not press the button within 30 s from time of first touch or a “1” if the infant did press the button within 30 s. Participants’ responses were tallied across stimuli and averaged to yield a single score (range of 0-1). A secondary coder scored 75% of the sessions; interobserver reliability was 100%.

**Results**

Preliminary analyses revealed that sex of the infant, or laboratory (Georgetown or Binghamton) did not produce any significant main effects or enter into any interactions.

Results show evidence of imitation from both the 2D touch screen image and 3D object. A one-way ANOVA across condition (baseline 2D, baseline 3D, 3D/2D, 2D/3D, 3D/3D, 2D/2D) revealed a main effect of condition, $F(5, 66) = 25.29, p < .001$, (partial $\eta^2 = .66$). As shown in Figure 3, post-hoc Student-Newman-Keuls tests revealed that the within-dimension groups (2D/2D and 3D/3D) performed significantly better than their baseline controls and the cross-dimension groups. Both 2D/3D and 3D/2D groups significantly exceeded baseline.
Figure 3. The mean imitation score of infants as a function of experimental condition: Baseline (2D or 3D), cross-dimension (2D/3D or 3D/2D) and within-dimension (3D/3D or 2D/2D). An asterisk indicates that the group performed significantly above baseline. Two asterisks indicate that the group performed above baseline and the other experimental conditions.

Discussion

The present work used a touch screen procedure in order to localize the source of the video deficit effect. The three aims of the study were achieved. We established the baseline for the 2D touch screen test and 3D object test. Both were low. We established that infants can imitate the target actions on the 2D touch screen and the 3D object. Both groups performed significantly above baseline and there were no differences between the within-dimension (2D/2D and 3D/3D) conditions. We also found that infants can imitate across dimensions. Both the 2D/3D and 3D/2D groups performed above baseline, with no differences between the cross-
dimension groups based on the direction of transfer. Notably both cross-dimension groups performed significantly worse than the within-dimension groups. That is, the cross-dimension groups exhibited the typical video deficit effect, even though the 2D medium was a touch screen, and this occurred whether the infants first observed the action on the 2D display and had to generalize to the 3D object or the reverse. Thus, the rate-limiting step in learning and acting via interactive media was the transfer of information between 2D and 3D.

From a theoretical point of view, use of 2D stimuli such as video and computers provide a good model for extending our knowledge about the nature and growth of representation during infancy. In particular, we examined the effects of the 2D stimuli on encoding and retrieval and found that encoding and retrieval from a 2D image was comparable to encoding and retrieval from a 3D object. That is, the infants did just as well in imitating in 2D/2D as they did in 3D/3D. They do not seem to have problems with using the 2D image itself. This is not the bottleneck.

This is a surprising finding for both the perceptual impoverishment and for dual representation accounts. From a perceptual impoverishment perspective, encoding and retrieval from a 2D presentation should have been limited. However, the successful performance of infants in the 2D/2D group demonstrates that the image was not so impoverished so as to block imitation. Furthermore, the 3D/2D and 2D/3D cross-dimension groups did not differ from one another suggesting that an impoverished 2D stimulus does not account for the video deficit effect. From a dual representation perspective, learning on a symbol itself would be expected to be diminished at this age because toddlers of this age are hypothesized to focus on the fundamental differences between 2D and 3D properties. Infants would be expected to not understand the significance of the object and action they viewed during the demonstration on the 2D touch screen, and therefore would fail to act on a televised display during test. In contrast, we
found that infants successfully imitated the action on the touch screen when the demonstration was also on the screen (2D/2D condition). It is possible, however, that the live adult demonstration of the function of the touch screen allowed infants to imitate from a 2D symbol when they otherwise would not interact with a 2D image.

These findings are consistent with the developmental representational flexibility account (e.g., Hayne, 2004). Following from this viewpoint, successful memory performance is dependent on the precision of the match between the cues present at the time of encoding and the cues available at retrieval; and/or a lack of cues at the time of retrieval may negatively impact performance. A lack of such cues may have compromised infants’ ability to retrieve the representation of the initial display in the cross-dimension test (Hayne, 2004). Because the 2D symbol shares fewer attributes with the 3D test objects, transferring of information across dimensions is more challenging from these media.

The present findings show that it is cognitively challenging to transfer information across dimensions, suggesting that during infancy the transfer of learning from computers or television to the real world may not be as easy as previously imagined. Further studies are needed to examine whether presenting the 2D images and 3D objects simultaneously enhances transfer ability, whether adding additional perceptual or verbal retrieval cues will decrease cognitive load and enhance transfer across dimensions, and whether adding a delay between demonstration and test will increase cognitive load and decrease overall performance. We are currently investigating these possibilities. Locating where the representation breaks down will provide us with important information regarding the emerging representational system and how it interacts with the perceptual and linguistic development and children’s use of interactive media.
The development of an imitation task that utilizes touch screen technology provides an important avenue for future research. It is critical to establish procedures that do not involve highly familiar products to be able to systematically dissect the learning process. Commercial products are difficult to study empirically because of different rates of exposure to such products. Development of viable and experimentally controlled analogues will allow us to make inferences about how infants learn in the context of television, computers, and other interactive new media marketed for children. From a practical point of view, these findings provide important information for parents, educators, and industry. There are a plethora of television programs, computer games, and “new media” designed for consumption by young children. However, at this point in time there is very little empirically based information available on infants’ learning from such media and their use of such information and learning to guide real-world actions. Thus there is a critical gap for people who want to design and use these media as effective teaching tools.

Overall, the present study establishes a new method to examine the video deficit effect and information transfer across dimensions during infancy. Further studies using this methodology will be able to probe infant learning from media and provide important insights into early infant learning among an ever-expanding array of media choices for very young children.
References


CHAPTER III: VERBAL CUES DO NOT FACILITATE 15-MONTH-OLDS’ TRANSFER OF LEARNING ACROSS 2D/3D

Abstract

Fifteen-month-olds have difficulty transferring information between 2D and 3D sources. The present study extends Zack et al.’s (2009) touch screen imitation task to examine whether the addition of nonsense or simple labels facilitates transfer of learning from 2D to 3D and 3D to 2D. Language cues did not augment infant imitation scores to above original transfer performance levels. There was an effect of transfer direction; infants only performed above baseline when language cues were added to the 2D/3D conditions.
Introduction

During the second year of life, infants begin to rapidly map novel words to objects (Bloom & Markson, 1998; Carey & Bartlett, 1978; Kay-Raining Bird & Chapman, 1998; Pruden, Hirsh-Pasek, Golinkoff, & Hennon, 2006). Naming is an important way to increase the salience of object properties and object similarities early in development (Waxman, 2008). Novel labels aid infants as young as 12 months in categorization, understanding category and object properties, and inductive inference (Booth & Waxman, 2002, 2003; Graham, Kilbreath, & Welder, 2004; Waxman, 2008; Waxman & Lidz, 2006). Language cues have also been found to facilitate imitative transfer of learning across dimensions (Barr & Wyss, 2008; Graham et al., 2004; Hayne & Herbert, 2004; Simcock & DeLoache, 2006). For example, eighteen-month-olds transferred learning from a 3-step task depicted in a picture book to 3D objects when the illustrations were color photos and accompanied by narration, but not when the illustrations were line drawings (Simcock & DeLoache, 2006).

Verbal Cues and Transfer of Learning

The standard infant imitation paradigm excludes verbal cues to prevent differences in imitation performance being attributed to age-related differences in language comprehension. However, when infants fail to imitate in the absence of meaningful language prompts, verbal cues have been added to the standard paradigm to measure their facilitative effects. In transfer of learning tasks using the imitation paradigm, the infant typically views a demonstration with one object and then is given a similar object that has a salient change (e.g., different color or form) at test (Graham et al., 2004; Herbert & Hayne, 2000; Lukowski, Wieber, & Bauer, 2009). For example, Graham and colleagues (2004) demonstrated a target action (e.g., tapping an object to produce a ringing sound) on a novel object. With the target object still in view, independent
groups of 13-month-olds were shown either a toy that differed in color, or a toy that differed in color and shape, or a toy that differed in color, shape, and texture. Without language cues, 13-month-olds extended the tapping action to only the toy that differed in color. However, when a novel label was added to the same procedure, 13-month-olds extended the tapping action to both the toy that differed in color and the toy that differed in color and shape. Perceptual information was not discounted entirely by the infants; they did not extend the tapping behavior to the toy that differed in color, shape, and texture. Thus, infants used the shared labels in addition to shape similarity to guide their inferences about sound properties.

Using a deferred imitation procedure, Herbert (2008) found that 12-month-olds were able to use simple language cues to generalize a demonstrated action to a novel puppet. Infants imitated significantly more target actions when presented with a simple label during demonstration and test (i.e., “Look. A puppet”) compared to when narration of the actions (i.e., “Off. Shake. On.”) was provided only during demonstrations. Using a similar procedure, Lukowski et al. (2009) demonstrated that even younger 9-month-olds can exploit narrative language cues when they are provided during encoding and retrieval. Nine-month-olds were able to generalize actions to novel, but functionally equivalent materials when narration of the actions was provided during demonstrations and a verbal description of the actions was provided again during test.

Transfer of learning from 2-dimensional (2D) sources such as books, television, and touch screens to real-world 3D objects is particularly challenging for young children in comparison to learning from live, face-to-face interactions with real objects (e.g., Barr & Hayne, 1999; Simcock & DeLoache, 2006; Zack, Barr, Gerhardstein, Dickerson, & Meltzoff, 2009). There is some evidence, however, that language cues enhance transfer. Ganea, Bloom Pickard,
and DeLoache (2008) examined transfer of learning between 2D images in a picture book and 3D objects in 15- and 18-month-old infants. They provided a nonsense label (e.g., “blicket”) to either a novel picture or object, such as an egg cup. During test, the infants’ task was to point to the matching “blicket” object or image. Transfer occurred at both ages and regardless of transfer direction - from 2D book image to 3D object or from 3D object to 2D book image. Researchers have also demonstrated that 2-year-olds are able to learn and extend novel labels presented on video to video exemplars that differ in size and color in the absence of a televised or live speaker (Scofield & Williams, 2009).

**Touch Screen Task**

One innovation of a recent transfer of learning study (Zack et al., 2009) was the combination of touch screen technology with the imitation approach. Independent groups of 15-month-old infants were randomly assigned to within-dimension (2D/2D, 3D/3D) and transfer dimension (3D/2D, 2D/3D) conditions. For the within-dimension conditions, an experimenter demonstrated an action by pushing a virtual button on a 2D touch screen or a button on a 3D object; infants were given the opportunity to imitate that action using the same touch screen image or object. For the 3D/2D transfer condition, an experimenter demonstrated the action on the 3D object and infants were given the opportunity to reproduce the action on a 2D touch screen image and vice versa for the 2D/3D condition. Infants in baseline only conditions did not view a demonstration before being shown the 3D test object or 2D touch screen image.

This study established a low baseline for the 2D touch screen test and 3D object test. It also established that infants can imitate target actions on the 2D touch screen and 3D object. Both within-dimension groups performed significantly above baseline and there were no differences between the within-dimension (2D/2D and 3D/3D) conditions. Infants were also able
to imitate across dimensions. Both the 2D/3D and 3D/2D transfer groups performed above baseline, with no differences between the transfer dimension groups. However, infants produced significantly fewer target actions in both transfer dimension conditions (2D/3D, 3D/2D) compared to their performance on within-dimension (3D/3D, 2D/2D) conditions.

Zack et al. (2009) proposed that poor representational flexibility provides a likely explanation for the transfer deficit. This explanation suggests that successful memory performance is dependent on the precision of the match between the cues present at the time of encoding and the cues available at retrieval. A lack of cues at the time of retrieval negatively impacts performance (Hayne, 2006). A lack of matching cues might have compromised infants’ ability to retrieve the representation of the initial display in the transfer test in Zack et al. (2009). Thus, in the present study, we increased the number of available retrieval cues by adding verbal cues during encoding and retrieval to examine their effect on transfer of learning across 2D/3D.

The Present Study

We extended Zack et al.’s (2009) touch screen task and added either a nonsense noun (e.g., dax) or object label (e.g., cow) and action verb (i.e., push) to the demonstration and test phases of the transfer conditions (2D/3D, 3D/2D). For the nonsense label conditions, we chose a noun because infants first learn to extract the noun from an infant-directed speech stream and map it to an object category (Booth & Waxman, 2003). We included phrases that were similar in length to the empty language cues provided during demonstrations in the Zack et al. (2009) study. For example, “Isn’t that fun?” was transformed into “Isn’t Dax fun?” in the present study. For the object label conditions, we did not embed the object label or action verb in a phrase, with the aim of making the cue as simplistic as possible. Prior research has shown that 17-month-olds look longer to a target when it is named using a single label compared to when it is labeled
within a sentence (Plunkett, 2006). In addition, mothers’ use of single labels during everyday mother-infant interactions in the home predicted infants’ future use of the labeled words (Brent & Siskind, 2001). Although verbs are learned less easily than nouns (Childers & Tomasello, 2006; Golinkoff & Hirsh-Pasek, 2006), the experimenter also said the word “push” during demonstrations to draw attention to the target action (Baldwin & Markman, 1989).

Prior research suggests that infants are successful in extracting and mapping a novel label early in the second year of life (Kay-Raining Bird & Chapman, 1998; Pruden et al., 2006), and that the addition of a novel verbal label can aide in inductive inference of a sound property (Graham et al., 2004) and facilitate transfer of learning from picture books to the real world (Ganea et al., 2008). Based on this research, we predicted that the addition of a verbal label would facilitate transfer across dimension by teaching infants that the image and the object are from the same object category. However, transfer from a real object to a touch screen presents an additional cognitive challenge not previously tested in the literature – acting on a 2D source in the same way you would act on a real object. Thus, if infants do not understand that a 2D image and actual object are functionally equivalent, then adding the novel label during demonstration and test will not increase imitation. The reverse could also be true; infants who view a demonstration on the 2D touch screen may not recognize its functional equivalence when presented with a 3D object at test.

**Method**

**Participants**

Seventy-one 15- to 16-month-old ($M = 15$ months, $17$ days, $SD = 15.8$, 30 male) full-term healthy infants and their parents were recruited through commercially available records, childcare centers, and by word of mouth. Participants were Caucasian ($n = 61$), Latino ($n = 3$),
African-American \((n = 2)\), Asian \((n = 1)\), and of mixed descent \((n = 4)\). The majority of infants were from middle- to upper-class \((\text{SES } M = 78.7, \text{ SD} = 13.8, 93\% \text{ reporting, Nakao & Treas, 1992})\), highly educated \((M = 17.6 \text{ years, } SD = 1.1, 98.6\% \text{ reporting})\) families. Six additional infants were excluded from the final sample due to equipment failure \((n = 2)\), experimenter error \((n = 1)\), or failure to touch the stimuli during the test phase \((n = 3)\).

Infants were randomly assigned to one of six groups: nonsense label 2D demo/3D test \((n = 12)\), nonsense label 3D demo/2D test \((n = 12)\), simple label 2D demo/3D test \((n = 16)\), simple label 3D demo/2D test \((n = 17)\), 3D baseline control \((n = 7)\), and 2D baseline control \((n = 7)\). The 3D baseline control and 2D baseline control groups were used to assess the spontaneous production of the target actions in the absence of the demonstration.

Using a partial replication approach, pooled 3D baseline and pooled 2D baseline groups were created by including 10 additional, age-matched, baseline control infants (5 infants in each group) that used the same stimuli and experimental procedures from our original touch screen study (Zack et al., 2009). These infants did not see a demonstration of the target actions prior to the test. There was no difference between the baseline scores of the current baseline groups and the previously collected baseline data \(t(20) = 1.31, p = .21\); therefore these data were collapsed for subsequent analyses. A follow-up t-test revealed no significant difference between the pooled 3D baseline group and pooled 2D baseline group, \(t(15) = 1.59, p = .13\).

**Apparatus, Experimental Set-up, and Procedure**

The non-commercially available stimuli, experimental set-up and procedure were identical to those reported in Zack et al. (2009) for the transfer dimension \((2D/3D, 3D/2D)\) conditions, with one adjustment: either nonsense label or simple label cues replaced empty language cues (e.g., isn’t that fun) at the beginning of each demonstration. For the nonsense label
conditions, the experimenter provided the cue “Dax” or “Modi” (e.g., “This is my friend Dax”) before performing the target action (see Table 1). The nonsense label phrases were delivered in the same order for all infants and the labels “Dax” and “Modi” were counterbalanced across stimuli. For the simple label conditions, the experimenter labeled each stimulus with its name (e.g., cow, duck, fire truck, or bus). In addition, the experimenter said the word “push” just before pressing the button during each demonstration. The experimenter spoke in a manner characteristic of “parentese” for all conditions.

The demonstration period was on average 34.53 seconds ($SD = 3.35$) per stimulus for the 3D objects and 36.13 seconds ($SD = 4.08$) per stimulus for the 2D touch screen images. Small variations in the demonstration times were due to occasional interruptions in the household (e.g., dog barking), technical problems on the touch screen, or infant fussiness. Infants in the baseline control groups did not participate in the demonstration phase. Rather, they were shown the test stimuli for the first time during the test phase.

Table 1

<table>
<thead>
<tr>
<th>Demonstration (MODI)</th>
<th>Test (MODI)</th>
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<tbody>
<tr>
<td>This is my friend MODI</td>
<td>Look, here's my friend MODI again</td>
</tr>
<tr>
<td>Isn't MODI fun?</td>
<td>Can you show me how MODI works?</td>
</tr>
<tr>
<td>Let's see how MODI works</td>
<td></td>
</tr>
<tr>
<td>What did MODI do?</td>
<td></td>
</tr>
<tr>
<td>MODI is a nice toy</td>
<td></td>
</tr>
<tr>
<td>One more time with MODI</td>
<td></td>
</tr>
</tbody>
</table>

*Note. The word “Dax” was substituted for “Modi” during the demonstration and test phases for the second stimulus.

**Test phase.** The test procedure was identical to Zack et al. (2009) except that the experimenter prompted infants in the transfer conditions with either the Dax or Modi cue
(nonsense label condition; see Table 1) or the object label (simple label condition) at the
beginning of the test. Infants in the baseline control groups were told, “Now it’s your turn”.
Infants were given 30s from time of first touch of the 3D object or 2D touch screen to imitate the
target action on each stimulus. Stimuli were presented in the same order as during the
demonstration for the experimental transfer groups.

**Infant language comprehension.** Caregivers \((n = 70)\) completed the short-form version
of the MacArthur Communicative Development Inventory (MCDI), an 89-word checklist of
words their infant understands and understands and says (Fenson et al., 2000). Infants’ percentile
rank for receptive language ability was within expected norms for the 15- to 16-month-old age
range \((M = 46.2, SD = 28.16)\). In addition, 46% of infants tested with the bus, 53% tested with
the fire truck, 59% tested with the cow, and 43% tested with the duck were reported to
understand the corresponding word.

**Coding and Reliability**

For each test trial, a primary coder scored if the infant pressed the button within 30 s from
the time of first touch (score = 1) or not (score = 0). Imitation scores were averaged across
stimuli to yield a single averaged score (range of 0-1). A secondary coder scored 55% of the
sessions; interobserver reliability was 96% \((κ = .90)\).

**Results**

Preliminary analyses revealed that infant sex, test stimuli, and nonsense label type (i.e.,
Dax or Modi) did not produce any significant main effects or enter into any interactions. Infants’
receptive vocabulary, as measured by the MCDI, was not significantly related to infant transfer
performance. These variables were therefore collapsed across all subsequent analyses.
We conducted a 2 (test dimension: 2D, 3D) x 3 (condition: nonsense label, simple label, baseline) analysis of variance (ANOVA) to examine the impact of language cues and transfer direction on infants’ imitation at test. The ANOVA revealed a main effect of condition, $F(2, 75) = 3.67, p = .03$, partial $\eta^2 = .09$. The main effect of condition was qualified by a test dimension $\times$ condition interaction, $F(2, 75) = 3.16, p = .048$, partial $\eta^2 = .08$. To assess the interaction, two separate one-way ANOVAs were conducted for each test dimension.

For the 3D test dimension, a one-way ANOVA across condition (2D/3D nonsense label, 2D/3D simple label, 3D baseline) revealed a reliable effect, $F(2, 37) = 3.77, p = .03, \eta^2 = .17$. Post hoc Student–Newman-Keuls tests revealed that both 2D demonstration/3D test nonsense label ($M = 0.29, SD = 0.33$) and simple label ($M = 0.34, SD = 0.35$) groups performed significantly better than the 3D baseline controls ($M = 0.04, SD = 0.14$).

For the 2D test dimension, a one-way ANOVA on condition (3D/2D nonsense label, 3D/2D simple label, 2D baseline) was marginally significant, $F(2, 38) = 3.15, p = .05, \eta^2 = .14$. Post hoc Student–Newman-Keuls tests indicated that neither 3D/2D nonsense label ($M = 0.46, SD = 0.45$) nor 3D/2D simple label ($M = 0.15, SD = 0.23$) groups performed significantly better than the 2D baseline controls ($M = 0.21, SD = 0.33$).

Additional chi-square analyses examined whether infants who had the object label (e.g., cow) in their receptive vocabulary were more likely to successfully transfer (i.e., push the button) for that object/image during test. Fisher’s exact tests revealed that there was no relationship between infant’s knowledge of the object label and transfer success for the first ($p = .69$, Fisher’s exact test) or second ($p = .68$, Fisher’s exact test) stimulus for the 3D test language groups (2D/3D nonsense label, 2D/3D simple label) or for the first ($p = 1.0$, Fisher’s exact test)
or second \((p = .42, \text{ Fisher’s exact test})\) stimulus for the 2D test language groups (3D/2D nonsense label, 3D/2D simple label).

**Discussion**

In the present study we examined whether the addition of nonsense or simple language cues to the transfer conditions (2D/3D, 3D/2D) from Zack et al. (2009) would facilitate transfer between dimensions. The findings revealed a significant difference in infant transfer performance based on the direction of transfer. Infants performed above baseline when language cues were present during encoding and retrieval for the 2D/3D conditions; however, infants’ performance did not exceed baseline when the demonstration was with the 3D object and test was with the corresponding 2D touch screen image.

This difference in performance is in contrast to the findings from Zack et al. (2009). In the original touch screen study, transfer dimension performance was above baseline for both the 2D/3D \((M = .38)\) and 3D/2D \((M = .33)\) groups, and these groups performed significantly worse than infants in the within dimension (3D/3D, 2D/2D) conditions. In this study, the addition of labels impaired infants’ performance in one direction (3D/2D) but not the other (2D/3D). Importantly, language cues did not augment imitation scores to above the original transfer performance levels for either transfer direction; infants remained far from reaching the within-dimension imitation performance found by Zack et al. (2009). Furthermore, examination of infant receptive vocabulary measures showed that even those infants with reported understanding of the object labels or infants with higher receptive language ability (as measured by the MCDI) did not show increased ability to transfer across dimension.

These results were somewhat surprising. Labeling has been found to facilitate categorization, imitation, and generalization in infants as young as 9 months, so why did
language cues not facilitate transfer on the touch screen task? One possibility is that the language cues created an additional cognitive load in an already difficult representational task. For example, Barr, Shuck, Salerno, Atkinson, and Linebarger (2010) argued that the addition of background music created additional cognitive load, thereby disrupting 6- to 18-month-old infants’ ability to encode actions presented in a video demonstration. Similarly, cognitive overload may have also been intensified in the nonsense label condition due to the complexity of the phrases.

The nonsense label “Dax” was embedded in a complex phrase and its placement within the phrase varied (first, middle, or final position) across demonstrations. Fernald and colleagues (as cited in Fernald, Pinto, Swingley, Weinberg, & McRoberts, 1998) found that 19-month-olds recognized a word presented in the middle or end of a sentence, whereas 15-month-olds only recognized the word if it was at the end of the sentence. Presenting a word in the middle of the sentence might be more taxing to young infants because they need to ignore the remaining auditory information while also mapping the word to the referent (Plunkett, 2006). Thus, our nonsense label phrases may have been too complex to aide transfer.

On the other hand, the language cues presented in the simple label conditions might not have been complex enough. The presentation of the object label in isolation rather than within a naming phrase might have impacted performance. For example, Keates and Graham (2008) found that 16-month-olds extended an action to an object that differed in color and size and an object that differed in color, size, and shape when the object was labeled as a count noun within a naming phrase during demonstration (e.g., “This is a blick”) but only extended the action to an object that differed in color and size when the word was presented in isolation (e.g., “Look. Blick.”). Similarly, Herbert (2008) found that providing a label marked as a count noun (i.e.,
“Look. A Puppet.”) during 3D encoding and 3D retrieval facilitated infants’ transfer of actions to a novel puppet.

Findings from a more recent study (Keates, Graham, & Ganea, 2010), however, suggest that the absence of a naming phrase cannot solely explain why infants in the touch screen transfer task failed to exploit the verbal cues. Keates et al. (2010) found that marking a novel label as a count noun within a naming phrase (e.g., “This is a blicket”, rather than “blicket”) did not facilitate 18-month-olds’ transfer of learning from a target action depicted in a picture book to a corresponding real-world, 3D object. Infants were not able to use the naming phrase (“Look, this is a blicket!”) to extend the target action to an object identical to that depicted in the book or to generalize to a 3D object that differed only in color. That is, the naming phrase did not help when infants were required to transfer between 2D and 3D. This finding is consistent with the results of the present study.

At first glance, these findings appear to be inconsistent with data from other picture book and transfer of learning tasks. For example, Ganea et al. (2008) found that 15- and 18-month-olds could use shared nonsense labels to transfer between picture book images and their real-world referents. However, there are two important things to note about this study. The 15-month-olds experienced difficulty with the task, and the authors had to adapt the procedure by cutting out the picture of the image to facilitate transfer. Second, the infants’ task was to point to the corresponding object or image, not manipulate it or demonstrate that it functions in the same way. We would argue that pointing to a corresponding object or image is an easier task than demonstrating its functional equivalence.

One unexpected, secondary finding was an effect of transfer dimension: infants tested with the 2D touch screen did not perform significantly above baseline. This effect was not found
in the original touch screen study when infants heard empty language (Zack et al., 2009). The language cues might have hurt infant transfer because infants were asked to use a symbol (language) on top of another symbol (2D image) (see DeLoache, 1991, 1995 for a similar argument) then act on the novel touch screen image, something they most likely had not encountered before. Alternatively, in the 2D/3D condition, infants were shown how the more difficult component (i.e., touch screen) of the transfer task worked during the demonstration phase. This finding is provisional and requires replication with touch screen studies.

Although language cues were not facilitative in the present study, researchers have shown that providing a narration of the target actions (rather than a shared label) during encoding begin to help infants around 18 months of age in generalization tasks (Hayne & Herbert, 2004; Simcock & DeLoache, 2006). Further empirical investigation is needed to examine whether the addition of narration will facilitate transfer on the touch screen task at different ages.

Taken together, the findings from this study suggest that the interrelationship between the language cues and a functional 2D image might have taxed infants’ already fragile representational system. Infants are novice language learners, and as such, might not be able to flexibly apply verbal cues when they are paired with a demanding perceptual transfer task. More research examining transfer of learning between real-world objects and touch screens is needed 1) to further explore this interrelationship and 2) determine why it might be more difficult for young children to transfer learning on tasks requiring them to understand the functional equivalence between 3D and 2D. Overall, the fact that language cues did not facilitate transfer illustrates how difficult this type of transfer task is for young children. The touch screen paradigm provides a good method of examining representational flexibility in young infants.
References


CHAPTER IV: MOTHERS ENHANCE INFANTS’ 2D-3D TRANSFER OF LEARNING:
THE ROLE OF EMOTIONAL RESPONSIVENESS & MATERNAL STRUCTURING

Abstract

Parent-child interaction research has typically focused on parent-infant exchanges during familiar activities (e.g., free play and book reading). One area that has received less attention is parental teaching of infants in novel situations. This study extends Zack, Barr, Gerhardstein, Dickerson, and Meltzoff’s (2009) touch screen procedure to examine maternal teaching and infant outcomes during a challenging transfer of learning task. Fifty 15-month-old infants and their mothers participated in this semi-naturalistic teaching task. Mothers were given a 3D object, and a static image of the object presented on a touch screen. Mothers had 5 minutes to teach their infant that a button on the real object works in the same way as a “virtual button” on the touch screen image (or vice versa). Overall, 64% of infants showed transfer of learning. Amount and type of maternal verbal input did not differ as a function of infant transfer success. A cluster analysis based on maternal teaching style (proportion of new verbal input), emotional responsiveness (turn taking, shared focus, maternal warmth, and infant involvement) and maternal structuring (amount of structure, teaching effectiveness) revealed two types of mother-infant dyads: high scaffold and medium scaffold. A logistic regression revealed scaffold type predicted infant transfer: infants were 22 times more likely to successfully transfer if they were in a high scaffold dyad, even after controlling for infant activity levels. This research suggests that early in development caregiver scaffolding drives transfer of learning between 2D and 3D.
Introduction

Parent-infant interactions are important for healthy social and cognitive development during early childhood. Research examining these dyadic interactions has typically focused on parent-infant exchanges during familiar activities such as toy play, feeding time, and book reading. One area that has received less attention is parental teaching of infants in novel, supportive contexts. This study takes a multi-faceted approach to describing maternal teaching and infant learning during a novel task – transfer of learning between 2-dimensional (2D) and 3-dimensional (3D) sources.

Parent-Child Interactions

Social interaction with parents and other significant adults help to shape the course of cognitive development during infancy and childhood (e.g., Bandura, 1977, 1986; Farrant & Reese, 2000; Rogoff, 1990; Vygotsky, 1978). Vygotsky’s (1978) social constructionist theory postulates that all cognitive functions develop through social experience. Children have a zone of proximal development, that is, the difference between what they are able to accomplish independently and what they can achieve with the instruction of a more experienced adult or peer. A range of different adult-child interactions have been examined, including non-parental caregivers, mothers, and fathers, although the bulk of research has thus far focused on mother-child interactions. Parents’ social support during parent-child interactions serves as a scaffold to young children, guiding them through new information, while adjusting to their child’s ability level. Research on the relationship between supportive parent-child interactions and young children’s cognitive development supports Vygotskian theory (e.g., DeLoache & DeMendoza, 1987; Farrant & Reese, 2000; Rogoff, 1990). Parents who engage in supportive interactions with their children are responsive, sensitive to the developmental level and needs of the child, are
engaged, use appropriate amounts and types of parental talk and provide guidance and structure through activities (Dodici, Draper, & Peterson, 2003). Accordingly, there are two primary measures that have been used to examine parent behavior during interactions: verbal input and emotional responsiveness/structuring. Each of these will be reviewed in turn.

**Verbal Input**

Verbal input during dyadic interactions prime infants for further social, cognitive, and language development. Preverbal infants incorporate phonological patterns present in their mother’s speech to their own babbling following contingent social feedback from the mother (Goldstein & Schwade, 2008). As infants’ language skills develop, they continue to be influenced by the frequency and quality of maternal verbal input; however maternal verbalizations differ significantly by SES background (Hart & Risley, 1995; Hoff, 2003; Hoff-Ginsberg, 1991; Rogoff, Mistry, Göncü, & Mosier, 1993). Specifically, mothers from a middle to high SES background talk more frequently with their children; engage in more elaborative and reciprocal conversation, rather than directive speech; and use more advanced and diverse vocabulary (Hoff-Ginsberg, 1991).

In their seminal, longitudinal study of early language, Hart and Risley (1995) found that infants growing up in low SES families heard more frequent negative talk and less frequent positive talk from their parents compared to infants of parents in middle SES families. In another longitudinal study, Hoff (2003) examined mother-child interactions during four everyday activities and found patterns in line with the above findings. High SES mothers (as measured by parent occupation and education) of one-and-a-half- to two-and-a-half-year-olds provided richer language learning environments during mealtime, dressing, toy play, and book reading than did low SES mothers of the same age children. During follow-up at age 4, children in high SES
families talked more, had higher productive vocabularies, and used more diverse vocabulary during spontaneous conversation. The importance of parental verbal input has also been widely investigated during joint book reading.

**Book reading.** Verbal scaffolding during book reading has been linked to increases in children’s literacy, school readiness and general symbolic processing (e.g., Reese, 1995; Scarborough & Dobrich, 1994). Individual mothers display different verbal interaction styles during book reading with infants and preschoolers, and they also vary in the degree to which their interaction style matches their child’s current ability (Britto, Brooks-Gunn, & Griffin, 2006; Haden, Reese, & Fivush, 1996; Ninio, 1980). For example, Ninio (1980) reported three dyadic interaction styles between mothers and their 17- to 22-month-old infants during a joint book reading situation. Label elicitors used *what* questions and provided confirmations following the infant’s response. Gesture elicitors used *where* questions, and the infants typically responded using a gesture (i.e., pointing), rather than a verbal response. Label providers, however, focused mainly on giving labels and did not expect the child to participate. Interaction style also influenced infants’ learning; vocabulary acquisition was highest for infants of caregivers who were label elicitors. Thus, there are degrees of scaffolding that mothers provide during interactions in the context of book reading and they differentially affect infant language learning.

Mothers also adjust their verbal scaffold during book reading based on the developmental level of their child (DeLoache & DeMendoza, 1987; Sénéchal, Cornell, & Broda, 1995). For example, DeLoache and DeMendoza (1987) examined mothers’ verbal behavior during picture book reading with their 12-, 15-, or 18-month-olds. Findings showed that the majority of mothers’ utterances were labels, but that mothers increased their use of elaborations and questions from 12 to 18 months. Overall, DeLoache and DeMendoza found that mothers provide
the structure in the context of book reading, but they reduce their scaffold and increase their
demands on the infants as infant language abilities increase.

**Media use.** Less research exists on parental verbal input during media-based interactions
with young children; however researchers are becoming more interested in parental scaffolding
of media use as technology created specifically for young children proliferates. Vygotskian
theory can also be applied to parent-child interactions surrounding 2D media use in order to
understand whether parents scaffold children’s use of computers and viewing of television
programming. Research on caregiver-preschooler interactions during a computer book reading
task found that caregiver presence (predominantly mothers) was important in learning from
computers (Lauricella, Barr, & Calvert, 2009). Specifically, Lauricella and colleagues (2009)
found that caregiver verbalizations differed depending on whether the caregiver or child operated
the computer mouse during the task. Similarly, Stoneman and Brody (1982) found that mothers
vary their verbal teaching to their preschoolers during television coviewing based on program
type (i.e., *Sesame Street* vs. a situation comedy). Mothers asked more questions about, and
labeled preacademic concepts more often during *Sesame Street* compared to the comedy.
Moreover, during *Sesame Street*, preschoolers followed their mothers lead and verbally engaged
in similar concepts and labeling.

In a study examining coviewing of an infant DVD designed to teaching word learning,
Fender, Richert, and Robb (2010) found parents varied in their level of scaffolding. High
scaffold parents were more likely to provide labels and descriptions of the video content, ask
their children to provide labels, and focus on the words presented in the DVD compared to low
scaffold parents who had more instances of talk unrelated to the DVD. Children of high scaffold
parents were also more likely to say the words featured on the DVD during coviewing.
Parents’ verbalizations (93% of participating caregivers were mothers) also influence their infants’ looking and responsiveness to infant-directed programming (Barr, Zack, Garcia, & Muentener, 2008). Barr et al. (2008) found that 12- to 18-month-old infants of parents who provided high levels of scaffolding by asking questions or providing labels and descriptions about the media responded more and looked significantly longer to the program than infants of parents who provided a low level of scaffolding.

In a follow-up study, Fidler, Zack, and Barr (2010) extended Barr et al.’s (2008) method to 6- and 9-month-old infants and also examined interactional quality (sense of togetherness and turn taking) in parent-infant dyads from both the original and follow-up studies. Consistent with Barr and colleagues findings, caregivers’ use of questions and labels and descriptions predicted infant looking to the video. In addition, caregiver-infant interactional quality was linked to infant looking behavior during the first 2 years of life, beyond the role played by caregiver verbal input and prior exposure to the program. Taken together, these results suggest that the presence of a contingent, social partner may have important influences on infants’ learning from 2D sources.

**Maternal Responsiveness and Structuring**

During the first six months of life, infants become more sensitive to the patterns and routines present in their daily interactions with their mother. By the end of their first year, infants have learned that interactions are based on reciprocal and interchangeable roles (Shaffer, 1977). It is through these interactions that infants discover their behavior can enter them into interactions with their mother and that their mother will provide a contingent response. In this sense, maternal responsiveness hinges not only on the mother’s response to the child, but also the child’s responses to the mother (Barnard & Kelly, 1990; Biringen, 2000; Biringen, Robinson, & Emde, 1998; Martin, 1989).
Maternal responsiveness and structuring has been indexed in a number of different ways, across a wide range of contexts and with diverse populations (e.g., Ainsworth, 1967; Barnard & Kelly, 1990; Biringen, 2000; Bornstein, 1989; Martin, 1989; Rogoff et al., 1993). Importantly, maternal responsiveness consistently predicts cognitive, language, and social outcomes across populations and throughout development (Bornstein, 1989, Bornstein et al., 2008; Kaplan, Burgess, Sliter, & Moreno, 2009; Tamis-LeMonda, Bornstein, & Baumwell, 2001). One well-documented assessment tool is the Emotional Availability Scale (Biringen, 2000; Biringen et al., 1998) which covers maternal and child behavior across six dimensions: children’s responsiveness and involvement of the adult; and for the caregiver - sensitivity, structuring, nonintrusiveness, and nonhostility. However, emotional availability (EA) has also been considered as just one aspect of maternal responsiveness in which one partner takes into consideration the affective state of another (Martin, 1989). Emotional availability also differs from other measures of maternal responsiveness in that it is typically assessed during free play or during the reunion following a separation from a caregiver as opposed to during teaching or problem-solving tasks (Biringen et al., 2005).

One similarity between the caregiver verbal input and responsiveness research is that mothers exhibit different patterns of behavior (e.g., Easterbrooks, Chaudhuri, & Gestsdottir, 2005; Fidler et al., 2010). Easterbrooks et al. (2005) were able to identify four types of EA in adolescent mother-infant dyads after assessing a 5 minute free play interaction. Mothers and their one-year-olds were classified as either low functioning, average, average with disengaged infant, or high functioning. Maternal structuring was the one EA factor that was the most distinguishable between groups (Easterbrooks et al., 2005).
More recently, aspects of maternal responsiveness and structuring have been investigated in other types of tasks such as reminiscing and book reading (Laible & Song, 2006) and in media coviewing (Fidler et al., 2010) contexts. Laible and Song (2006) were interested in the emotional quality of interactions between mothers and their preschool age children during a discussion about a past emotional event and joint book reading. Some measures of emotional quality included maternal warmth and interest, child warmth and involvement, and the dyad’s sense of togetherness and shared attention. These emotional quality measures predicted children’s socioemotional development regardless of context. Although the terminology and measurement scales have differed across studies, this body of research illustrates the importance of the reciprocal relationship between mother and child for both immediate and future outcomes. Mothers and infants must adapt and respond to each other and develop a synchrony in their interactions to promote future learning (Barnard & Kelly, 1990).

**Verbal Input, Responsiveness, and Structuring during Teaching Tasks**

Verbal input, responsiveness and structuring are also important contributors to children’s learning in structured teaching tasks. Two overarching teaching components have been observed in maternal teaching of problem-solving and puzzle tasks: 1) affective quality, responsiveness and support and 2) direct teaching and instruction including verbal input (Barnard & Kelly, 1990; Britto et al., 2006; Goldberg, Lojkasek, Gartner, & Corter, 1989; Maccoby & Martin, 1983). This suggests there is significant overlap between mother-child behaviors exhibited during general interactions and teaching situations.

The aforementioned research has focused on instances in which caregivers were asked to engage in a task with their child, but not explicitly to “teach” their child a specific skill or behavior. For example, during a free play situation that includes different colored blocks in a
given set of toys, a mother may take the initiative and use the blocks to teach her child about colors; however this was not the task the researcher presented to her. Therefore a child outcome, in this case learning a color, could not be assessed across individual dyads. In the same way, the measures of maternal behavior are not being described for a specific task with a designated outcome.

Research examining maternal teaching has largely relied on older age groups or familiar tasks (e.g., Britto et al., 2006; Laosa, 1980). Laosa (1980) asked mothers to participate in a 5 minute task in which they were asked to teach their 5-year-old how to make a Tinker toy model like a model the dyad had been given. Anglo-American mothers primarily guided their children through verbal praise and questions as well as using nonverbal cues to draw children’s attention to specific parts of the task. Modeling and physical affection rarely occurred. Chicano mothers, however, provided modeling in addition to using nonverbal cues during the task. There was only about a 30% success rate on the task; unfortunately differences in maternal behavior were not compared by success on the task as the purpose of the study was to validate a technique for measuring teaching across cultural groups.

Britto et al. (2006) took a more comprehensive approach to examining both verbal input and structuring during low-income mothers book reading and teaching of a puzzle task with their preschool-age children. Different teaching patterns emerged based on mothers’ verbal and nonverbal interactions during the teaching task: mothers either provided low amounts of support and low amounts of teaching, high amounts of support but low amounts of teaching or high support and high amounts of teaching. High support and teaching was related to better language skills in the preschoolers. Britto and colleagues did not examine these interaction patterns with regard to children’s success on the puzzle task, as this was not the focus on their study.
Caregiver teaching has been examined in younger, infant populations, although not to the same extent and with limited reporting of task outcomes. Brachfeld-Child (1986) found that parents use a variety of teaching strategies when asked to teach their 8-month-olds a new skill – putting a cube in a cup. Mothers and fathers distributed their time in the same way by primarily using attention-getting behaviors, making the test object more accessible, and vocalizing. During the teaching task, parents also held objects still, guided infants hands to the object, used pointing gestures, and prohibited either locomotion or play with objects. Infant success on the task was not reported on its own or in relation to the parental teaching behaviors.

Banerjee and Tamis-LeMonda (2007) examined maternal teaching during one of two tasks, either pointing to body parts in a book or building a tower with blocks. Maternal teaching was measured using 3 subscales from the Nursing Comprehensive Satellite Teaching Scale (NCAST): sensitivity, cognitive growth fostering, and social-emotional growth fostering. Each subscale includes a series of yes/no questions which indicate whether a specific behavior was observed (Barnard & Kelly, 1990). Although one question does indicate whether the child successfully completes the task or not, infants can complete the task with the aid of their mother and be considered “successful”. Moreover, infant task success is not the aim of the NCAST; rather it is to assess parent-child interactions during a teaching task. A combined total teaching score from summing the subscales predicted Bayley scores at 14 months but the individual subscales did not. Infants’ attempts to complete the task were measured, however the success of those attempts was not reported (Banerjee & Tamis-LeMonda, 2007).

Dixon, LeVine, Richman, and Brazelton (1984) did provide the frequency of successful infants on a series of maternal teaching tasks in their longitudinal study comparing African and American mothers’ interactions with their infants. Task success, however, was only included as
an incidental measure; the only relation between maternal teaching and task outcome reported
was how mothers responded if their infant succeeded on the task.

Taken together, prior research on maternal teaching with young children has primarily
focused on providing broad descriptions of maternal behavior without connecting the behavior to
child outcomes on a specific task. While most tasks have examined child outcomes in some form
(e.g., persistence during the task or cognitive skills at a later date), immediate success on
teaching tasks, especially in relation to maternal and infant behaviors has been largely
disregarded (e.g., Banerjee & Tamis-LeMonda, 2007; Britto et al., 2006). In addition, maternal
modeling of the task outcome or verbal instructions to complete the task is often permitted (e.g.,
Brachfeld-Child, 1986; Dixon et al., 1984) making it impossible to disentangle children’s ability
to complete the task in the absence of modeling from their task achievement with the addition of
modeling.

In tasks that have examined child success, (e.g., Laosa, 1980), the success rate has been
low, even with additional maternal support. This suggests that the task may not have been
developmentally appropriate for the age group tested. In order to examine the benefits of
maternal scaffolding, a task needs to be devised with two criteria in mind: 1) the infant needs to
be able to physically engage in the task and 2) it should be a task in which infants have
demonstrated a difficulty in completing or understanding on their own. Transfer of learning
between 2D and 3D tasks meet these criteria. Researchers have demonstrated that infants have
difficulty in transfer of learning between 2D and 3D (e.g., Barr & Hayne, 1999; Zack et al.,
2009). As such, a transfer of learning task provides the ideal context in which to examine both
maternal teaching and infant outcomes. Maternal teaching during 2D-3D transfer of learning
situations, however, has been largely unexplored by researchers.
Transfer of Learning between 2D and 3D

Transfer of learning from 2D sources such as books, television, and touch screens to real-world, 3D objects is particularly challenging for young children in comparison to learning from live, face-to-face interactions with real objects (e.g., Anderson & Pempek, 2005; Barr & Hayne, 1999; Simcock & DeLoache, 2006; Zack et al., 2009). Zack and colleagues (2009) combined a novel touch screen procedure with the imitation approach to examine transfer of learning from 3D to 2D as well as 2D to 3D.

Independent groups of infants were randomly assigned to within-dimension (2D/2D, 3D/3D) and cross-dimension (3D/2D, 2D/3D) conditions. For the within-dimension conditions, an experimenter demonstrated an action by pushing a virtual button on a 2D screen or a button on a 3D object; infants were given the opportunity to imitate that action using the same touch screen image or object. For the 3D/2D condition, an experimenter demonstrated the action on the 3D object and infants were given the opportunity to reproduce the action on a 2D touch screen image of the object and vice versa for the 2D/3D condition. Infants in baseline only conditions did not view a demonstration before being shown the test 3D object or 2D touch screen image.

This study established a low baseline for the 2D touch screen test and 3D object test. It also established that infants can imitate target actions on the 2D touch screen and 3D object. Both within-dimension groups performed significantly above baseline and there were no differences between infant performance in the within-dimension (2D/2D and 3D/3D) conditions. Infants can also imitate across dimensions. Both the 2D/3D and 3D/2D groups performed above baseline, with no differences between the cross-dimension groups. However, infants produced significantly fewer target actions in both cross-dimension conditions (2D/3D, 3D/2D) compared to their performance on within-dimension (3D/3D, 2D/2D) conditions.
In a second experiment, Zack and colleagues (see Experiment 2) extended Zack et al.’s (2009) touch screen task to examine whether the addition of nonsense or simple labels facilitates transfer of learning from 2D to 3D and 3D to 2D. Language cues did not augment infant imitation scores to above original transfer performance levels. Zack and colleagues (2009, Experiment 2) propose that the transfer deficit may stem from an inability to relate 2D images to the corresponding 3D objects in the real world and understand they can function in the same way. Both Experiments 1 and 2 illustrated how difficult transfer of learning can be for young children.

Nonetheless, research on parent-child interactions and teaching tasks as well as Vygotskian theory suggest that high quality interactions between infants and caregivers should provide a scaffold under challenging learning conditions. That is, caregiver scaffolding might play a vital role in infants’ transfer of learning between 2D and 3D. Thus, in the present study, mothers were asked to teach the touch screen transfer of learning task to their infants.

The Present Study

The touch screen transfer conditions (Zack et al., 2009; Experiment 2) were adapted into a semi-naturalistic teaching task. Mothers were given a 3D object, and a static image of the object presented on a touch screen. Mothers had 5 minutes to teach their infant that a button on the real object works in the same way as a “virtual button” on the touch screen image (or vice versa).

There were three primary goals in this study. The first goal was to examine infants’ ability to transfer learning between 2D and 3D in the context of a novel teaching situation. This will extend prior research in two specific areas. Researchers examining maternal teaching during parent-infant interactions have primarily focused on the quality of the interaction and not
examined how quality is related to child success on the task (e.g., Banerjee and Tamis-LeMonda, 2007; Brachfeld-Child, 1986; Britto et al., 2006; Dixon et al., 1984; Laosa, 1980). In fact, child success during teaching tasks has been largely unreported. Because examining child success has not been a goal in these past studies, modeling of the target action or assistance of the mother in achieving the goal has been permitted (e.g., Laosa, 1980). For the present teaching task, mothers were not permitted to verbally instruct or model for the child how the test object or image works to gauge infants’ true ability to transfer learning across dimensions. This will also extend the literature on transfer of learning between 2D and 3D during infancy (see Experiments 1 and 2; Zack et al., 2009).

The second goal was to describe mothers’ semi-naturalistic teaching of 2D to 3D information transfer. A plethora of research has shown positive relationships between parental verbal input and responsiveness with future cognitive and social outcomes; however it remains unclear how parents teach in a media context and how maternal teaching directly influences immediate learning. This study also draws together both verbal input, responsiveness, and structuring measures to capture all aspects of maternal teaching.

The final goal was to examine what maternal teaching and infant factors contribute to transfer of learning between 2D and 3D. Interactive media contexts are increasingly becoming part of the day-to-day environments of infants and their caregivers. It is important to understand whether, and in what ways parental scaffolding may enrich these experiences and contribute to infant learning.
Method

Participants

Fifty 15- to 16-month-old (25 male) full-term healthy infants and their mothers were recruited through commercially available records, childcare centers, and by word of mouth. Mother-infant dyads were visited in their homes between January, 2008 and December, 2009. Infants ranged in age from 15 months and 1 day to 16 months and 18 days ($M = 15$ months, 16 days, $SD = 11.0$ days). Participants were Caucasian ($n = 39$), Latino ($n = 3$), Asian ($n = 3$) and of mixed descent ($n = 5$). The majority of infants were from middle- to upper-class, highly educated families. Their parents’ mean educational attainment was 17.84 years ($SD = 0.5$) based on 100% of the sample, and their mean rank of socioeconomic status (Nakao & Treas, 1992) was 79.7 ($SD = 12.2$) based on 98% of the sample. Educational attainment, occupational status, and annual income are the major components of socioeconomic status. The SEI ranks 503 occupations listed in the 1980 US census on a scale of 1 to 100, with higher status occupations (e.g., physician) being accorded higher ranks (Nakao & Treas, 1992).

Mother-infant dyads were randomly assigned to one of two conditions (3D demo object/2D test image or 2D demo image/3D test object), with 25 mother-infant dyads per condition. The primary language spoken at home and during the task was English for 96% of the sample ($n = 48$). Two mothers spoke in English and Spanish during the task as this is how the mothers would normally interact with their child at home. An additional 5 mother-infant dyads were excluded from the final sample due to equipment failure ($n = 1$), maternal interference ($n = 2$), infant fussiness ($n = 1$) and an inability to transcribe the session ($n=1$).
Apparatus

A subset of two stimuli was chosen from the four stimuli used in Zack et al. (2009). Neither of the stimulus objects was commercially available.

3D stimuli. Two novel objects were created from a black button box (16.5 wide x 15 tall x 5.5 cm) and decorated to create a school bus and a cow. The bus has a slightly recessed rectangle-shaped button (2.2 x 3 cm) on the right surface in the middle of the box. The cow has a slightly recessed circular button (2.2 x 2.2 cm in diameter) on the left surface in the middle of the box. Pressing the button activates a switch which produces a different sound for each object: a horn honking (bus) or a cow mooing.

2D stimuli & touch screen. Digital photos were taken of the two previously described 3D objects and depicted on a 17 in. LCD touch screen. The touch screen was connected to a laptop and programmed with the images of the 3D objects using software used in various touch screen tests of infants (e.g., Zack et al., 2009). The button areas were programmed such that pressing the “virtual button” produced the same sound as pressing the actual button on the 3D object. The images were equated in size to the 3D object at approximately the same viewing distance.

Experimental set-up. Two lap tables (each 61 wide x 32 tall x 37.5 cm deep) were placed side-by-side on the floor and used as the testing surface for both conditions. The 3D object was placed on one table and the touch screen on the second table (see Figure 1). Mothers were randomly assigned to either the bus or cow stimulus for use in teaching the transfer task. Mothers and their infants sat on the floor at the lap tables, facing the 2D touch screen and 3D object. The 3D object and touch screen were covered with a black cloth until the start of the session.
Figure 1. Experimental set-up for the touch screen teaching task.

Procedure

An experimenter described the study and obtained informed consent from the mother. Mothers were also shown an illustration of the task set-up and given written instructions describing the set-up, goals, and restrictions for the task.

Mothers were instructed to teach their infant about the relationship between the 3D object and 2D touch screen image, that is, that a button on the real object works in the same way as a “virtual button” on a touch screen (or vice versa). For example, a mother assigned to the 2D demonstration/3D test condition was instructed that she could interact with or discuss either the 3D object or touch screen. However, mothers were given one caveat. They could not directly point out the 3D button, push the 3D button, or say push with regard to the 3D object. The mothers’ goal was for the infant to press the 3D button within 5 minutes time.

One experimenter videotaped the session from behind the two lap tables such that the mother and infant’s faces were visible at all times. A second experimenter was positioned behind the mother-infant dyad and videotaped the mother and infants such that their arms and the touch screen and object were visible at all times. The session ended when the infant successfully pressed the button on the test 3D object (2D demonstration/3D test condition) or 2D touch screen
image (3D demonstration/2D test condition) or at 5 minutes, whichever came first. Infants received a certificate for their participation.

**Questionnaires**

**Household & infant media use.** Mothers were asked to estimate their typical daily household television use and amount of time their infant was exposed to television/videos on a typical day.

**Infant language comprehension and production.** All mothers completed the short-form version of the MacArthur Communicative Development Inventory (CDI), an 89-word checklist of words their infant understands and understands and says (Fenson et al., 2000). Percentile rank was determined by the age and gender of the infant for both language comprehension and production. Infants’ language ability was within expected norms for the 15- to 16-month-old age range. An additional 4 words were added to the inventory – cow, bus, button, and same – as we anticipated mothers would use these words while teaching the transfer task.

**Coding – Task Variables**

**Transfer success.** A primary coder scored from videotape whether infants performed the target action (pressing the button) on the test object (2D/3D condition) or test image (3D/2D condition). A transfer score of ‘0’ was given if the infant did not press the button within 5 minutes from the start of the session or a transfer score of ‘1’ if the infant did press the button. A secondary coder scored 50% of the sessions; inter-observer reliability was 100%.

**Session length.** The 2D touch screen and 3D object were covered with a cloth before the start of the session. The start of the session was marked when the mother removed the black cloth. The session end time was marked as when the infant successfully transferred or when 5 minutes had expired, whichever came first.
Latency to touch 3D object and 2D touch screen image. Latency to touch the 3D object and 2D touch screen image was calculated as the difference between the session start time and first touch of the 3D object and the first touch of the 2D touch screen image. This was coded for both the mother and the infant. A Pearson product–moment correlation yielded an interobserver reliability coefficient of .99 for the mother and .99 for the infant based on 20% of the sessions for both the 3D object and the 2D touch screen image.

Latency to success. Latency to success was calculated two ways: latency to success from the start of the session and latency to success from infant’s first touch of the test stimulus. Latency to success from infant’s first touch of the test stimulus was included to be in line with the manner success was coded in previous experimental studies using touch screens (see Experiments 1 and 2). Infants who did not successfully transfer on the task received a latency time of 5 minutes, the maximum amount of time dyads had to complete the task.

Coding – Maternal Behavior

Types of maternal verbal input. Mothers’ verbalizations were transcribed verbatim from each session. A detailed coding scheme was developed based on book reading and infant-directed media coviewing studies (Barr et al., 2008; DeLoache & DeMendoza, 1987; Fidler et al., 2010; Potter & Haynes, 2000). Additional verbal input categories specific to this transfer of learning task were added to the coding scheme. The following categories were coded.

Attentional vocatives. Attentional vocatives were defined as a mother’s attempts to obtain the infant’s attention verbally by using an utterance, “Look” or “Look at that” or by saying the infant’s name.
**Questions.** Questions were defined as instances in which the mother requested a verbal or nonverbal response from the infant, such as “Where are the eyes?”, “What does the cow say?”, “Does this one beep?”, “Can you do it?” or “Is that a cow?”.

**Labels.** Labels were defined as single referents provided for the infant, such as “eyes”, or “It’s yellow”. Descriptions were defined as utterances longer than single words or labels, such as “The girl is riding the bus” or “The cow can say moo”. Specific types of labels were also coded: object label (cow, bus), object sound (beep, honk, moo) and the use of the word button (only related to the demonstration stimulus).

**Matching.** Matching was defined as instances in which the mother indicated that the 2D image and 3D object are the same or similar in some way, for example, “This one has eyes and this one has eyes,” or “They make the same noise,” or “One cow, two cows”.

**Push/press or push/press the button.** This was defined as instances in which the mother used the word “press” or “push” or said the phrase “Press or push the button” with regard to the demonstration stimulus.

**Proxy for push.** Proxy for push was defined as instances in which the mother indirectly asked her infant to push/press/touch the button on the demonstration stimulus or test stimulus, for example, “Can you make this cow say moo?” or “Can you do that [referring to infant pushing the button on demonstration stimulus] on that one?” Mothers used this strategy as a way to request that the infant “push the button” on the demonstration or test stimuli without actually using that phrase.

**Encouragements.** Encouragements were defined as positive feedback by the mother related to the infant’s previous vocalization or behavior, such as “Good job”, “That’s right, that’s its eye” or “You can do it”.

76
**Shaping.** Shaping was defined as feedback by the mother to correct her infant’s previous vocalization or behavior or indicate they were in error, such as, “No not there, here” or “You need to push a little harder”.

**Feedback.** Feedback was defined as any instance in which the mother provided shaping (e.g., “You need to move your finger over to touch the button”), encouragement (e.g., “Good pushing!”), or discouragement (e.g., “Don’t climb on the table.”).

**Highlighting.** Highlighting was defined as instances in which the mother combined verbal and nonverbal information to simultaneously explain and show where the button is. For example, the mother might say “You push the circle”, as she traced her finger around the outside of the button or “It’s right here”, as she pointed to the button. Highlighting could only occur with reference to the demonstration stimulus.

**Cause and effect.** Cause and effect was defined as an explanation by the mother that if you do X, Y will happen, such as “If you push here, the cow will moo”. It also included instances in which the mother provided language regarding a cause and effect relationship in tandem with a button push, e.g., the mother said “This is how I make him go moo” as she pushed the button on the demonstration stimulus.

**Describe infant action.** Describe infant action was defined as the mother narrating the actions of her infant, such as saying “You are touching the eyes” as the infant touched the eyes on the stimulus.

**Off-topic.** Off-topic verbalization were defined as instances in which the mother referenced something unrelated to the transfer task, such as “Are you hungry?” or “You have your book”.

77
**Uncodable verbalizations.** I was unable to transcribe .01% of what mothers said during the session due to background noise or the mother speaking too softly.

The total frequency of each category of maternal verbal input was calculated across the teaching task. Then for each category a proportional measure as a function of the total number of maternal utterances was calculated. Proportions were used because of individual differences in verbal scaffolding and overall talkativeness during the task (see also Haden et al., 1996). Each utterance could receive more than one code, i.e., “Push the button on the cow” would receive a “push the button” code and a “label” code. Overall reliability for maternal verbal input calculated for 20 of the 50 transcripts was 90% ($\kappa = .89$). Disagreements were resolved through discussion.

**Total number of maternal utterances.** The total number of utterances was calculated for each mother. An utterance was defined as a string of words separated from other speech by a pause, or as a grammatically complete sequence of words (Sénéchal et al., 1995).

**Proportion of “new” verbal input.** The transcripts were also coded to examine how much “new” information the mother provided during the task. An utterance was coded as “new” in the transcript if the mother had not provided the same information within the previous 10 utterances. An utterance was defined as repetitive if the mother had provided the same content (Reese & Fivush, 1993) within the previous 10 utterances (see Appendix). A Pearson product–moment correlation yielded an interobserver reliability coefficient of .96 based on 30% of the sessions.

**Maternal pointing.** Pointing was defined as the number of times the mother used her index finger to point toward the 3D object or 2D touch screen image during the task. This also included instances in which mothers extended their index finger to directly touch the object or screen. The frequency of points to the 3D object and 2D image were calculated separately. A
total frequency of points was calculated by summing the number of points to the 3D object and number of points to the 2D image. In addition, the frequency of maternal points from the 3D object to the 2D image (e.g., pointing from 3D eye to 2D eye on the cow), 2D image to 3D object, to the overall 3D object or overall 2D image and maternal points to the 3D button (3D/2D condition) or 2D button (2D/3D condition) were calculated.

To control for differences in session length across dyads, a “pointing rate” was calculated. The rate was calculated by taking the total number of times the mother pointed and dividing by each individual dyads’ session length (maximum time = 5 minutes). For example, a mother who pointed 10 times during a session that lasted 4 minutes would receive a rate of 2.5 instances of pointing per minute. This approach has been used in other tasks examining mother-child interactions in a teaching context (e.g., Laosa, 1980). An individual rate was also calculated for maternal points to the 3D object as a whole, points to the 2D touch screen image as a whole, points to the 3D button (3D/2D condition), and points to the 2D button (2D/3D condition). Reliability was 86% ($\kappa = .83$) based on 20% of the data.

**Maternal button pushes.** A coder scored each time the mother pushed the button on the demonstration stimulus; the rules of the task stipulated that mothers were not permitted to push the button on the test stimulus. A “button push rate” was calculated to control for differences in session length across dyads, just as it was done for pointing. The rate was calculated by taking the total number of times the mother pushed the button on the demonstration stimulus and dividing by the individual session length for each dyad (maximum time = 5 minutes). Reliability was 89% ($\kappa = .76$) based on 34% of the data.
Coding - Infant Behavior

**Infant vocalizations.** Infant vocalizations were coded as either positive/neutral or negative. Negative vocalizations were classified as instances in which the infant cried or sounded frustrated or upset; all other vocalizations were coded as positive. Only vocalizations directed toward the task were coded. There were five additional words that we coded when the infant said as they were most relevant to the task: object label (cow or bus), object feature (e.g., eye, girl, ear), the word “button”, or the word “push”.

**Infant pointing.** Pointing was defined as the number of times the infant pointed toward the 3D object or 2D touch screen during the task. This also included instances in which infants extended their index finger to directly touch the object or screen. The frequency of points to the 3D object and 2D image were calculated separately. A total frequency of points was also calculated by summing the number of points to the 3D object and number of points to the 2D image. To control for differences in session length across dyads, a “pointing rate” was calculated for the 3D object, the 2D image and both the 3D object and 2D image together. The rate was calculated by taking the total number of times the infant pointed and dividing by each individual dyads’ session length (maximum time = 5 minutes). Reliability was 85% (κ = .74) based on 24% of the data.

**Infant button pushes.** A coder scored each time the infant pushed the button on the demonstration stimulus; a button push on the test stimulus was coded as *transfer success*. A “button push rate” was calculated to control for differences in session length across dyads, just as it was done for pointing. The rate was calculated by taking the total number of times the infant pushed the button on the demonstration stimulus and dividing by the individual session length
for each dyad (maximum time = 5 minutes). Reliability was 90% ($\kappa = .81$) based on 20% of the data.

**Infant activity level.** Because this study was conducted under semi-naturalistic conditions in infants’ homes and mothers had control over their infants’ position (e.g., standing or sitting) during the task, we wanted to report how active (low or moderate) the infant was during the task. Low activity was coded if infants were primarily situated in one location (e.g., on the mother’s lap), whereas moderate activity was coded if infant frequently moved around the teaching task area. Activity level was not scored for two infants who completed the task in less than 1 minute because the session did not last enough to make a stable judgment. Reliability was 93% ($\kappa = .84$) based on 30% of the data.

**Coding – Global Scales**

A series of emotional responsiveness and maternal structuring measures were coded by 2 independent observers. Emotional responsiveness and maternal structuring were not coded for two mother-infant dyads in which the infants successfully transferred in less than 1 minute; the session did not last long enough to accurately assess the measures.

**Emotional responsiveness.** Emotional responsiveness was coded on the basis of four dimensions, shared focus, turn taking, maternal warmth, and infant involvement. The four dimensions were adapted from a coding scheme developed by Laible and Song (2006). For each dimension, dyads were rated on a five-point scale (with 1 = low amount of behavior and 5 = high amount of behavior).

**Shared focus.** Shared focus was defined as a sense of togetherness, shared meaning, and unity with regard to the task; mother and infant “being on the same page”. High shared focus was defined as consistent and high-quality interaction between the mother and infant with regard to
the task. In these interactions, the mother and infant were engaged in the same aspect of the task for close to the entire session. Low shared focus was defined as the mother and infant being engaged in completely different aspects of the task for most of the session, or a child who is engaged in off-topic play for most of the session. Reliability was 81% ($\kappa = .74$) based on 32% of the data.

**Turn taking.** Turn taking was defined as the degree to which caregivers and infants engaged in conversational exchanges (verbal or nonverbal back-and-forth) with regard to the task. High turn taking was characterized by significant amounts of mutual and fluent communication with regards to the task. Mothers appropriately responded to their infant’s requests and interests for all of or almost the entire session. Low turn taking was characterized by the absence of this type of exchange. Reliability was 81% ($\kappa = .7$) based on 32% of the data.

**Maternal warmth.** Maternal warmth was defined as the degree of sensitivity that a mother displays toward her infant’s affective cues; including promptness & appropriateness of reactions, amount of physical affection, positive affect and tone of voice. High maternal warmth was characterized by the use of an engaging, affectionate style with the infant throughout the session. Encouragement and praise occur frequently throughout the session. Low maternal warmth was characterized by frequent instances of frustration with the infant and no instances of encouragement or praise of the infant; a mother going through the motions of the task without being engaging. Reliability was 94% ($\kappa = .88$) based on 32% of the data.

**Infant involvement.** Infant involvement was defined as how engaged the infant was in the task; the amount of responsiveness toward the mother’s teaching. High infant involvement was characterized by consistent infant interactions with the mother and active verbal or nonverbal responses to a mother’s directives or requests. Low infant involvement was
characterized by an infant being unreceptive to a mother’s directives or requests; an infant mostly interested in off-task play. Reliability was 94% ($\kappa = .91$) based on 32% of the data.

**Total emotional responsiveness.** An overall emotional responsiveness score was calculated by summing the dyads’ scores for each emotional responsiveness measure (maximum score = 20). Reliability was 88% ($\kappa = .82$) based on 32% of the data.

**Maternal structuring.** Maternal structuring was coded on the basis of 4 dimensions: teaching style, teaching effectiveness, amount of structure, and nonverbal teaching; each dimension is dichotomous. These dimensions were designed based on the nature of the transfer of learning teaching task as well as structuring measures reported by other research groups (Barnard & Kelly, 1990; Biringen, 2000; Goldberg et al., 1989).

**Teaching style.** Teaching style was coded on a 2-point scale and characterized by the innovation of strategy use by the mother to structure infant participation in the task. A mother with a *diverse style* employed a variety of strategies to teach the task. A mother with a *repetitive style* used the same few strategies over and over to teach the task. Reliability was 93% ($\kappa = .86$) based on 30% of the data.

**Teaching effectiveness.** Teaching effectiveness was coded on a 2-point scale and was defined as how successful the mother was in organizing her infant’s attention, motivation and involvement in the task for greater than 50% of the dyad’s session length. An *effective* mother influenced her infant’s behavior or took the infant’s reactions into account greater than 50% of the time. The following is an example of a mother who was effective at structuring the task. *An infant tries to push the 3D button on the demonstration tool but doesn’t push hard enough for it to make a sound. The mother requests the infant push harder but the child doesn’t try again so the mother guides the infant’s finger back to the button. The infant successfully pushes the button*
and the mother says “you did it!” The mom then requests the infant “push the button” to make sure she can do it on her own. The infant then pushes the 3D button without her mother’s help. A mother who was not effective did not influence her infant’s behavior or take the infant’s reactions into account greater than 50% of the time. Reliability was 93% (κ = .87) based on 30% of the data.

**Amount of structure.** Amount of structure was coded on a 2-point scale and was characterized by how often the mother provided structure, that is organized the infant’s attention, motivation, and involvement in the task and how often the mother attempted to teach the transfer task. A mother was classified as either providing an optimal amount of structure or too little/too much structure. Mothers who provided an optimal amount of structuring would let their infants be autonomous while also guiding their behavior to reach the goal. For example, if an infant was repeatedly pushing the button on the demonstration stimulus, the mother might redirect her infant, either physically or verbally, to the test stimulus and say that it works in the same way. Reliability was 93% (κ = .84) based on 30% of the data.

**Nonverbal teaching.** Nonverbal teaching was coded on a 2-point scale and was characterized by the use of regular nonverbal behaviors, such as pointing, moving the 3D object, or repositioning the child or use of “extra” nonverbal strategies such as holding the 3D object up next to the touch screen image; all nonverbal strategies had to be accompanied by verbal support. A high amount of nonverbal teaching was characterized by frequent use of nonverbal strategies throughout the task. A limited amount of nonverbal teaching was characterized by sporadic to rare use of any nonverbal structuring and no instances of “extra” strategy use. Reliability was 100% (κ = 1.0) based on 30% of the data.
Results

In the present study, we had three primary goals: 1) to examine infants’ ability to transfer learning between 2D and 3D in the context of a teaching situation, 2) to describe mothers’ semi-naturalistic teaching of 2D to 3D information transfer and 3) to identify maternal and infant factors which contribute to transfer of learning between 2D and 3D.

Transfer Success

We first examined infants’ success on the task, as the breakdown between successful and unsuccessful mother-infant dyads provides the foundation for future descriptive statistics and analyses. Sixty-four percent of infants \( (n = 32) \) exhibited transfer of learning on the touch screen task. Transfer success did not differ by condition; 64% of infants were successful in the 2D/3D condition and 64% were successful in the 3D/2D condition. A 2(success: transfer, no transfer) x 2(stimulus: cow, bus) chi-square revealed a significant effect of stimulus, \( \chi^2 (1, N = 50) = 5.56, p = .018 \). Infants tested with the bus (80%) were significantly more likely to successfully transfer than infants tested with the cow (48%). Lastly, a 2(success: transfer, no transfer) x 2(sex: male, female) chi-square revealed a significant trend for differences between males (52%) and females (76%) on transfer success, \( \chi^2 (1, N = 50) = 3.13, p = .08 \).

Descriptive Statistics

A series of t-tests were conducted to compare whether infants who succeeded on the task differed demographically from infants who did not succeed on the task. As shown in Table 1, there were no significant differences in any of the demographic variables (infant age in months, average household television usage per day, average infant exposure to television per day, infant receptive or productive vocabulary, parent education, and socioeconomic status) for infants who successfully transferred and infants who did not successfully transfer, all \( t \) values < 1.
Table 1

*Mean demographic characteristics for infants by transfer success*

<table>
<thead>
<tr>
<th>DEMOGRAPHICS</th>
<th>INFANT TRANSFER (n=32)</th>
<th>NO INFANT TRANSFER (n=18)</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age in months</td>
<td>15.52 ± 0.36</td>
<td>15.53 ± 0.38</td>
<td>0.89</td>
</tr>
<tr>
<td>Household media hours/day</td>
<td>2.29 ± 1.81</td>
<td>1.83 ± 1.37</td>
<td>0.35</td>
</tr>
<tr>
<td>Infant media hours/day</td>
<td>0.56 ± 0.83</td>
<td>0.47 ± 0.98</td>
<td>0.74</td>
</tr>
<tr>
<td>MCDI comprehension percentile</td>
<td>43.88 ± 34.95</td>
<td>38.00 ± 30.03</td>
<td>0.55</td>
</tr>
<tr>
<td>MCDI production percentile</td>
<td>41.44 ± 29.60</td>
<td>41.83 ± 35.63</td>
<td>0.97</td>
</tr>
<tr>
<td>Education</td>
<td>17.8 ± 0.6</td>
<td>17.9 ± 0.5</td>
<td>0.64</td>
</tr>
<tr>
<td>SES</td>
<td>80.6 ± 12.7</td>
<td>78.1 ± 11.4</td>
<td>0.48</td>
</tr>
</tbody>
</table>

*Note.* All Ts<1.

**Maternal Teaching**

In this section, I report the verbal and nonverbal teaching strategies displayed by mothers during the task. A transfer of learning teaching task has not been conducted with mothers and their young infants before; therefore it is important to provide a detailed description of what mothers do when presented with this type of novel situation.

**Maternal verbalizations.** Because this was a teaching task, we anticipated mothers would employ different verbal strategies and that specific types of verbalizations would predict transfer success. Prior research has shown that caregiver’s use of questions and labels and descriptions may be important influences on children’s learning from 2D sources such as books.
and television. For example, Barr et al. (2008) found that 12- to 18-month-old infants looked and responded more to an infant-directed video when their mothers provided high levels of scaffolding in the form of questions and labels and descriptions. However, in the context of a teaching task such as this, asking too many questions could actually be detrimental to infants’ performance if the mother isn’t providing useful, directive information. Requesting labels or asking open ended questions may also be more appropriate for older children who have more developed vocabularies (Fletcher & Reese, 2005). On the other hand, the use of labeling, especially in the form of matching cues to relate the 3D object and 2D image could be facilitative in this transfer of learning task.

One of the goals of this study was to describe the teaching context, and thus the types of verbalizations mothers used to teach. First, I describe the proportion of mothers who gave specific types of verbal input. Next, I discuss the specific types and prevalence of verbal strategies that mothers used during task. I then take an in depth look at mothers’ use of utterances during the first and second minute of the task, how mothers’ input changes across time, and whether it varies by infant transfer success. Lastly, I examine the proportion of new information that mothers provided during the task.

**Types of maternal verbal input.** Some interesting findings emerged when examining the types of verbalizations mothers used throughout the task. All mothers encouraged their infants and asked a question on at least one occasion during the task. Surprisingly, 22% of the mothers (n = 11) never labeled the cow or bus while teaching. Despite this fact, 9 of those mothers had infants who successfully transferred, including one infant who completed the task in less than 1 minute. Six of the 11 mothers reported their child did not understand the corresponding object
label (cow or bus) when she filled out the MCDI. Although a large percentage of mothers did not label the object, all but 1 mother referenced the noise the object makes (e.g., moo).

In terms of the goal of the transfer task, eleven of the mothers \( (n = 11) \) did not label the button on the demonstration stimulus; the rules of the task stipulated that they could not label the button on the test stimulus and these mothers may have been more cautious in their interpretation. Eighteen percent of mothers \( (n = 9) \) never directed the child to “push” or “push the button” on the demonstration stimulus; however 78% \( (n = 11) \) and 76% \( (n = 12) \) of mothers indirectly asked their child to push the button (e.g., “can you make that cow go moo?”) on the demonstration or test stimulus, respectively. Taken together, 92% of mothers either directly or indirectly asked her child to produce the target action (i.e., push the button) during the task.

Verbal strategy use. There were a number of other strategies I hypothesized would be prevalent during the task: cause and effect, shaping, highlighting, and matching; however, strategy use generally occurred less frequently than expected. Only 40% of mothers \( (n = 20) \) made a cause and effect statement (e.g., “if you touch right here the cow will moo”) and of those who did use the strategy it was used infrequently, 20% \( (n = 10) \) only provided the strategy once. Approximately half of mothers \( (n = 26) \) provided feedback to shape her child’s previous behavior or utterance (e.g., “you need to push harder”). The combination of a verbal statement (e.g., “right here”) with nonverbal action (e.g., mother traces her finger around the outside of the button) to highlight the location of the button was used by 66% of mothers \( (n = 33) \) on at least one occasion. Eighty-two percent of mothers \( (n = 41) \) indicated to her infant that the 2D image and 3D object “matched” or were similar in some way (e.g., “this one has eyes and this one has eyes”). Of those 41 mothers, approximately half \( (n = 21) \) provided a matching cue less than 5 times during the task.
Maternal verbal input as a function of time. I conducted a minute-by-minute analysis to examine how mothers initially used verbal information to teach the relationship between the 2D image and 3D object. All 50 dyads participated in minute 1. Two infants were successful prior to the start of the second minute so minute 2 only included 48 dyads. By the start of minute 3, another 8 infants had succeeded on the task therefore the minute-by-minute analysis was not run for minutes 3, 4 or 5. A repeated measures analysis was conducted across minute to assess the differences in mother’s verbal teaching for infants who successfully transferred on the task and infants who did not transfer.

I predicted that there would be differences in amount and use of different types of mothers’ verbal strategies for infants who succeeded on the task. Specifically, it was hypothesized that mothers of successful infants would use more verbal matching cues (including labeling) and strategies such as highlighting, shaping, and explaining a cause and effect relationship, while asking fewer questions overall. I calculated the average proportion of each verbal strategy type for mothers of infants who transferred and the average proportion of each verbal strategy type for mothers of infants who did not transfer for minute 1 and minute 2 (see Table 2). A proportion of diverse verbal input was also calculated for each minute by tallying the total number of different coding categories a mother used then dividing by the total number of possible codes a mother could receive (11 possible coding categories). For example, a mother who provided a label, asked a question, and encouraged her infant would receive a diversity score of 3 for that minute. The score of 3 was divided by the possible 11 to receive a diversity proportion of 0.27.

A 2(infant success) × 2(time segment: minute 1, minute 2) ANOVA with repeated measures across time segment yielded a main effect of time segment, $F(12, 35) = 3.17, p = .01,$
partial $\eta^2 = .52$. There was no significant main effect of infant success, $F(1, 58) = .64, p = .80$, partial $\eta^2 = .18$ and no infant success by time segment interaction, $F(12, 35) = .94, p = .52$, partial $\eta^2 = .24$. Contrary to my predictions, mother verbalizations did not differ as a function of whether infants succeeded or not on the transfer task.

Follow-up univariate ANOVAs were performed to determine which maternal verbal strategies were significantly different between minute 1 and minute 2. Results revealed that the proportion of mothers’ utterances that were labels, $F(1, 46) = 6.6, p = .01$, partial $\eta^2 = .13$, indirect requests for the child to “push” (proxy for push), $F(1, 46) = 12.47, p = .001$, partial $\eta^2 = .21$, descriptions of their infant’s action, $F(1, 46) = 8.5, p = .005$, partial $\eta^2 = .16$, and diversity of utterances, $F(1, 46) = 4.57, p = .04$, partial $\eta^2 = .09$, significantly increased from minute 1 to minute 2. Conversely, the proportion of mothers’ utterances that were attention-getting phrases significantly decreased, $F(1, 46) = 12.62, p = .001$, partial $\eta^2 = .22$, from minute 1 to minute 2 (see Table 2). Overall, labels and questions comprised the highest proportion of mothers’ utterances, irrespective of minute. This is consistent with data from book reading and television coviewing studies (Barr et al., 2008; DeLoache & DeMendoza, 1987).

1 Four infants successfully transferred within the first 10 seconds of minute 2 on the task. The repeated measures ANOVA was rerun excluding these 4 infants; the pattern of results was almost identical, with only the diversity of utterances no longer being significant from minute 1 to minute 2.
Table 2

Proportion of mothers’ verbal teaching strategies used during the first and second minute of the task

<table>
<thead>
<tr>
<th>VERBAL TEACHING</th>
<th>MINUTE 1</th>
<th></th>
<th></th>
<th></th>
<th>MINUTE 2</th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>INFANT</td>
<td>NO INFANT</td>
<td>TOTAL</td>
<td>INFANT</td>
<td>NO INFANT</td>
<td>TOTAL</td>
<td>INFANT</td>
<td>NO INFANT</td>
</tr>
<tr>
<td></td>
<td>TRANSFER</td>
<td>TRANSFER</td>
<td>(n=48)</td>
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<td>(n=48)</td>
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<td>Questions</td>
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<td>M</td>
<td>SD</td>
<td>M</td>
<td>SD</td>
<td>M</td>
<td>SD</td>
</tr>
<tr>
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<td>.17</td>
<td>.09</td>
<td>.18</td>
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<td>.08</td>
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<td>M</td>
<td>SD</td>
<td>M</td>
<td>SD</td>
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<td>SD</td>
<td>M</td>
<td>SD</td>
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<td>SD</td>
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<td>SD</td>
<td>M</td>
<td>SD</td>
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<tr>
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<td>.07</td>
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<td>SD</td>
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<td>.09</td>
<td>.11</td>
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<td>Highlight</td>
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<td>SD</td>
<td>M</td>
<td>SD</td>
<td>M</td>
<td>SD</td>
<td>M</td>
<td>SD</td>
</tr>
<tr>
<td></td>
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<td>.02</td>
<td>.02</td>
<td>.02</td>
<td>.02</td>
<td>.02</td>
<td>.02</td>
<td>.06</td>
</tr>
<tr>
<td>Cause &amp; Effect</td>
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<td>SD</td>
<td>M</td>
<td>SD</td>
<td>M</td>
<td>SD</td>
<td>M</td>
<td>SD</td>
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<td>.02</td>
<td>.00</td>
<td>.01</td>
<td>.01</td>
<td>.02</td>
<td>.00</td>
<td>.01</td>
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<tr>
<td>Describe Action</td>
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<td>M</td>
<td>SD</td>
<td>M</td>
<td>SD</td>
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<td>.03</td>
<td>.02</td>
<td>.03</td>
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<td>.03</td>
<td>.03</td>
<td>.04</td>
</tr>
<tr>
<td>Off-Topic</td>
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<td>M</td>
<td>SD</td>
<td>M</td>
<td>SD</td>
<td>M</td>
<td>SD</td>
</tr>
<tr>
<td></td>
<td>.02</td>
<td>.03</td>
<td>.03</td>
<td>.03</td>
<td>.02</td>
<td>.03</td>
<td>.03</td>
<td>.05</td>
</tr>
<tr>
<td>Diversity of Utterances</td>
<td>M</td>
<td>SD</td>
<td>M</td>
<td>SD</td>
<td>M</td>
<td>SD</td>
<td>M</td>
<td>SD</td>
</tr>
<tr>
<td></td>
<td>.23</td>
<td>.07</td>
<td>.23</td>
<td>.06</td>
<td>.23</td>
<td>.07</td>
<td>.34</td>
<td>.22</td>
</tr>
</tbody>
</table>
**Diverse vs. repetitive teaching.** Although specific types of maternal verbal input did not differ by infant transfer success, I hypothesized that the organization of maternal verbalizations may influence transfer. Specifically, mothers who varied their verbal teaching strategies minute-by-minute and did not provide the same information repeatedly would be more successful in facilitating infant transfer. On average, 62% ($SD = 12\%$; range = 39% - 92%) of mothers’ utterances were new information. An independent samples t-test was conducted to compare the proportion of new information provided by mothers of infants who succeeded on the task and mothers of infants who did not succeed on the task. There was a significant difference in the proportion of new information provided by mothers of infants who successfully transferred ($M = 0.65$, $SD = 0.10$) and mothers of infants who did not successfully transfer ($M = 0.57$, $SD = 0.12$), $t(48) = 2.31$, $p = .03$.

**Pointing.** Verbalizations can act as a powerful tool for enriching nonverbal information in certain joint attention contexts (Flom & Pick, 2003). Therefore, I was also interested in the relationship between mothers’ use of matching cues and pointing between the 2D image and 3D object. The proportion of maternal verbal matching strategies and the frequency of maternal pointing to the 2D image, the 3D object and between 3D and 2D (or vice versa) were investigated using Pearson product-moment correlations. There was a positive correlation between the frequency of mothers’ points to the 3D object and the frequency of her points to the 2D touch screen image (see Table 3). In addition, all mothers pointed at least one time during the task. There was no correlation between the proportion of mothers’ verbal matching strategy use and pointing to the 2D image or the 3D object. There was, however, a moderate, positive correlation between the proportion of verbal matching strategies and maternal pointing from 3D to 2D and the proportion of verbal matching strategies and maternal pointing from 2D to 3D (see
Table 3). Surprisingly, however, very few mothers ever pointed from 3D to 2D ($n = 12$) or from 2D to 3D ($n = 9$) during the task.

Table 3

*First order correlations between proportions of mother verbal matching strategy use, and maternal pointing*

<table>
<thead>
<tr>
<th></th>
<th>Matching</th>
<th>3D Object</th>
<th>2D Image</th>
<th>3D to 2D</th>
</tr>
</thead>
<tbody>
<tr>
<td>3D Object</td>
<td>.19</td>
<td>-</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2D Image</td>
<td>.21</td>
<td>.34*</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>3D to 2D</td>
<td>.46**</td>
<td>.08</td>
<td>-.05</td>
<td>-</td>
</tr>
<tr>
<td>2D to 3D</td>
<td>.30**</td>
<td>-.06</td>
<td>-.04</td>
<td>.42**</td>
</tr>
</tbody>
</table>

*Note.* *Correlation is significant at the 0.05 level (2-tailed). **Correlation is significant at the 0.01 level (2-tailed).*

Next, I was interested in whether there were significant differences in the rate of pointing for mothers of infants who successfully transferred compared to mothers of infants who did not successfully transfer. A one-way between groups multivariate analysis of variance (MANOVA) was performed to investigate whether there were differences in the rate of different types of maternal points for infants who successfully transferred and infants who did not. Four dependent variables were included: rate of pointing to 3D object, rate of pointing to 2D image, rate of pointing to the 3D button, and rate of pointing to the 2D button. The MANOVA yielded no significant main effect of infant success, $F(5, 44) = 0.78, p = .57$, partial $\eta^2 = .08$. Mothers of infants who succeeded on the task did not have a significantly higher rate of pointing (3D overall, 2D overall, 3D button, 2D button, or overall object/image) compared to infants who did not succeed on the task (see Table 4).
Table 4

*Rate of maternal pointing per minute for infants who successfully transferred and infants who did not successfully transfer*

<table>
<thead>
<tr>
<th>MATERNAL POINTING</th>
<th>TRANSFER SUCCESS</th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>INFANT TRANSFER</td>
<td>NO INFANT TRANSFER</td>
<td>TOTAL</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(n=32)</td>
<td>(n=18)</td>
<td>(n=50)</td>
<td></td>
</tr>
<tr>
<td>M</td>
<td>SD</td>
<td>M</td>
<td>SD</td>
<td>M</td>
</tr>
<tr>
<td>3D Object - Overall</td>
<td>0.92</td>
<td>1.08</td>
<td>0.70</td>
<td>0.72</td>
</tr>
<tr>
<td>2D Image - Overall</td>
<td>1.32</td>
<td>1.86</td>
<td>1.16</td>
<td>1.09</td>
</tr>
<tr>
<td>3D Button</td>
<td>0.81</td>
<td>1.32</td>
<td>0.40</td>
<td>0.79</td>
</tr>
<tr>
<td>2D Button</td>
<td>0.91</td>
<td>1.26</td>
<td>0.82</td>
<td>1.26</td>
</tr>
<tr>
<td>Overall Object/Image</td>
<td>2.40</td>
<td>2.28</td>
<td>1.93</td>
<td>1.34</td>
</tr>
</tbody>
</table>

**Button push demonstrations.** I would argue that an essential element of the teaching task was for the mother to physically model for her infant how the demonstration stimulus worked.

An independent samples t-test was conducted to compare the rate of button pushes by mothers of infants who succeeded on the task and mothers of infants who did not succeed on the task. There was no significant difference in the rate of button pushes by mothers of infants who successfully transferred (M = 2.96, SD = 2.14) and mothers of infants who did not successfully transfer (M = 2.69, SD = 1.46), t(48) = .48, p = .64.

**Infant Behaviors**

Although mothers were the partner in the dyad responsible for teaching, infants also bring their own distinct characteristics and behaviors to the interaction (Barnard & Kelly, 1990). Just as there is little known about how mothers teach a 2D-3D transfer of learning task, there is little
know about how infants respond in this type of situation. Thus, in this section, I will describe the infants’ verbal and nonverbal behavior and how it relates to transfer success.

**Infant vocalizations.** All but one infant vocalized during the teaching task. Overall, infants’ vocalizations reflects their positive engagement in the task; 22% of infants ($n = 11$) ever produced a negative vocalization and of those eleven infants, half ($n = 6$) negatively vocalized only one or two times. Consistent with their age and productive vocabulary ability (see Table 1), most infants did not verbalize during their session. Only one infant labeled the stimulus (cow), 4 infants labeled a feature of the object/image (e.g., eye), and one infant said “button”. Twenty percent of infants ($n = 10$) made the object noise (8 mooed and 2 said “beep”). No child said the word “push”.

As in Experiment 2, I wanted to examine whether there were differences in infant’s understanding of specific words related to the task, as reported by the mother on the MCDI. Half of the infants who successfully transferred ($n = 16$) understood the label of the object (i.e., bus or cow) that they were tested with and half did not. Thirteen of the successful infants (40.6%) understood the word “button”; 15 did not understand the word button and the data was unreported for 4 infants. Only three of the infants who did not transfer (17%) understood the word button; data was unreported for 3 infants. Of the infants who successfully transferred ($n = 32$), only 37.5% understood the word “push” ($n = 12$). Only four of the infants who did not transfer (22%) understood the word push. No child was reported to understand the word “same”; however more than half of mothers ($n = 28$) used the word at least one time while teaching.

**Pointing.** Pointing is an important indicator of emerging joint attention in 12- to 18-month-olds (Butterworth, 2001). Pointing may occur for multiple reasons. It is most commonly used by 12- to 18-month-olds for the following reasons: (1) to indicate that the infant is
requesting a label; (2) to indicate that the infant wants the parent to share the directed object of interest; (3) to nonverbally respond to a parent question about a recognized object. In all cases, pointing to the 3D object or 2D touch screen image indicates active engagement with the task. Similar to the analysis with the mothers, I was interested in the relationship between the number of infant vocalizations and frequency of infant pointing. A Pearson product-moment correlation revealed a moderate, positive correlation between the total amount of infant pointing and both the total amount of infant vocalizations and amount of positive infant vocalizations. There was no correlation between infant pointing and negative vocalizations. In addition, a strong, positive relationship was found between infant points to the 3D object and infant points to the 2D image (see Table 5).

Table 5

*First order correlations between the frequency of infant vocalizations and infant pointing*

<table>
<thead>
<tr>
<th></th>
<th>Total Vocalizations</th>
<th>Positive Vocalizations</th>
<th>Negative Vocalizations</th>
<th>Total Pointing</th>
<th>Pointing 3D Object</th>
</tr>
</thead>
<tbody>
<tr>
<td>Positive Vocalizations</td>
<td>.98**</td>
<td>-</td>
<td></td>
<td></td>
<td></td>
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<td>Negative Vocalizations</td>
<td>.27</td>
<td>.05</td>
<td>-</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total Pointing</td>
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<td>.43**</td>
<td>.00</td>
<td>.88**</td>
<td>-</td>
</tr>
<tr>
<td>Pointing 3D Object</td>
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<td>.30*</td>
<td>.08</td>
<td>.89**</td>
<td>.57**</td>
</tr>
<tr>
<td>Pointing 2D Image</td>
<td>.42**</td>
<td>.46**</td>
<td>-.08</td>
<td>.89**</td>
<td>.57**</td>
</tr>
</tbody>
</table>

*Correlation is significant at the 0.05 level (2-tailed). **Correlation is significant at the 0.01 level (2-tailed).*

An infant “pointing rate” was calculated for all infant points, infant points to 3D and infant points to 2D, in order to control for differences in session length across dyads, just as it was calculated for the mothers. A one-way between groups MANOVA was performed to investigate whether the rate of infant points was different for infants who successfully transferred
and infants who did not transfer. Three dependent variables were included: rate of pointing to 3D object, rate of pointing to 2D image, and the rate of overall pointing. The MANOVA yielded no significant main effect of infant success, $F(2, 47) = 1.47, p = .24$, partial $\eta^2 = .06$. Infants who succeeded on the task did not have a significantly higher rate of pointing (overall, 3D, or 2D) compared to infants who did not succeed on the task (see Table 6).

Table 6

*Rate of infant pointing per minute for infants who successfully transferred and infants who did not successfully transfer*

<table>
<thead>
<tr>
<th>TRANSFER SUCCESS</th>
<th>INFANT TRANSFER (n=32)</th>
<th>NO INFANT TRANSFER (n=18)</th>
<th>TOTAL (n=50)</th>
</tr>
</thead>
<tbody>
<tr>
<td>INFANT POINTING</td>
<td>M</td>
<td>SD</td>
<td>M</td>
</tr>
<tr>
<td>3D Object</td>
<td>2.97</td>
<td>3.20</td>
<td>1.65</td>
</tr>
<tr>
<td>2D Image</td>
<td>2.41</td>
<td>1.71</td>
<td>2.28</td>
</tr>
<tr>
<td>Both 2D and 3D</td>
<td>5.38</td>
<td>4.15</td>
<td>3.93</td>
</tr>
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</table>

**Button pushes.** All but 4 of the infants pushed the button on the demonstration stimulus during the task; 3 of those infants demonstrated transfer of learning. An independent samples t-test was conducted to compare the rate of button pushes on the demonstration stimulus for infants who succeeded on the task and infants who did not succeed on the task. There was no significant difference in the rate of button pushes by infants who successfully transferred ($M = 2.98, SD = 2.88$) and infants who did not successfully transfer ($M = 2.03, SD = 1.20$), $t(45) = 1.64, p = .11$.

The frequency of button pushes was exceptionally high for 2 of the infants (40 and 60 total button pushes); this produced a kurtosis statistic well above the acceptable level (14.11).
The kurtosis statistic was reduced to .08 when the 2 outliers were removed from the analysis. The independent samples t-test was rerun without the outliers. There remained no significant difference between the rate of button pushes for infants who successfully transferred \( (M = 2.49, SD = 2.1) \) and infants who did not successfully transfer \( (M = 2.03, SD = 1.20) \), \( t(46) = .97, p = .34 \).

**Latency to success.** Latency to success (i.e., pushing the button on the test stimulus) was calculated in two ways: from the start of the session and from infants’ first touch of the test stimulus. We were primarily interested in latency from the start of the session since that is when the teaching task began. In Experiments 1 and 2, infants were given 30 seconds from the time of their first touch of the test object/image to complete the task. Thus, we also wanted to document average latency to success from first touch of the test stimulus (i.e., the touch screen image in the 3D/2D condition and the 3D object in the 2D/3D condition). Infants who were not successful on the task \( (n = 18) \) automatically received the maximum total session time of 5 minutes; they will be excluded from the remainder of this section.

The average latency to success from the start of the session and time of first touch of the test stimulus was 2.68 minutes \( (SD = 1.38 \text{ min}) \) and 1.57 minutes \( (SD = 1.27 \text{ min}) \), respectively. Table 7 shows the minute-by-minute breakdown of latency to success from the start of the session and infants’ first touch of test stimulus.

We also conducted a series of t-tests to examine whether latency to success from the start of the session differed by condition, stimulus, or gender. Latency to success did not significantly differ between infants in the 2D/3D group \( (M = 2.68 \text{ min}, SD = 1.29 \text{ min}) \) and 3D/2D group \( (M = 2.69 \text{ min}, SD = 1.51 \text{ min}) \), \( t(30) = .03, p = .97 \). Infants tested with the bus \( (M = 2.83 \text{ min}, SD = 1.30 \text{ min}) \) did not successfully transfer significantly faster than infants tested with the cow \( (M =
2.45 min, $SD = 1.54$ min), $t(30) = .74$, $p = .47$. There was also not a significant difference
between latency to success for females ($M = 2.7$ min, $SD = 1.23$ min) and males ($M = 2.66$ min,
$SD = 1.63$ min), $t(30) = .08$, $p = .94$.

Table 7

*Minute-by-minute breakdown of latency to infant success from the start of the session and from infants’ first touch of the test stimulus*

<table>
<thead>
<tr>
<th>Latency to Success</th>
<th>from Start of Session</th>
<th># of infants (n = 32)</th>
<th>from 1st Touch of Test Stimulus</th>
<th># of infants (n = 32)</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt; 1 minute</td>
<td></td>
<td>2</td>
<td></td>
<td>14</td>
</tr>
<tr>
<td>&lt; 2 minutes</td>
<td></td>
<td>8</td>
<td></td>
<td>7</td>
</tr>
<tr>
<td>&lt; 3 minutes</td>
<td></td>
<td>10</td>
<td></td>
<td>7</td>
</tr>
<tr>
<td>&lt; 4 minutes</td>
<td></td>
<td>5</td>
<td></td>
<td>4</td>
</tr>
<tr>
<td>&lt; 5 minutes</td>
<td></td>
<td>7</td>
<td></td>
<td>0</td>
</tr>
</tbody>
</table>

**Activity level.** Recent research in the child care field has found a discrepancy between
the lack of observed sex differences in the activity level of young children and sex differences in
the activity level reported by teachers (Winer & Phillips, 2010). Thus, I first examined whether
there were sex differences in activity level during this transfer of learning task. Consistent with
Winer and Phillips (2010), results from a Spearman rank correlation showed no significant
correlation between gender and activity level, $r(46) = .00$, $p = 1.0$. A follow-up $2$(gender: male,
female) x $2$(activity level: low, moderate) chi-square revealed no significant effect of gender,
$\chi^2(1, N = 48) = .00$, $p = 1.0$. I conducted a chi-square to examine whether infant activity level was
related to transfer success. A $2$(infant success: transfer, no transfer) x $2$(activity level: low,
moderate) chi-square revealed a significant effect of activity level, $\chi^2(1, N = 48) = 6.4$, $p = .011$.
Low activity level infants were significantly more likely to transfer than moderate activity level
infants.
Mother-Infant Dyad – Verbal & Nonverbal Behaviors

The individual results for the mother and infant illustrate few behavioral differences in the maternal teaching and infant behaviors for mother-infant dyads in which the infant successfully transferred and for mother-infant dyads in which the infant did not successfully transfer. However, a focus solely on the individual units within a dyad does not tell the whole story. Increasingly, researchers are emphasizing the importance of examining the social dimension of behavior (Barr et al., 2008; Bornstein & Tamnis-LeMonda, 2001; Fidler et al., 2010) and considering the dyad as a unit of analysis (Bornstein & Tamis-LeMonda, 2001; Goldstein & Schwade, 2008; Gros-Louis, West, Goldstein, & King, 2006; Martin, 1989; Rogoff, 1990; Uzgiris, Benson, Kruper, & Vasek, 1989; Vygotsky, 1978). This shift to examining the dyad requires exploring the relationship between mother and infant behaviors on both specific (e.g., relationship between mother and infant button pushes) and more global (e.g., amount of turn taking) levels. Thus, the next step was to explore the relationship between mother and infant behaviors within the dyad.

Maternal utterances and infant vocalizations. The relationship between the number of maternal utterances and number and type (positive or negative) of infant vocalizations produced across dyads was examined using a Pearson product-moment correlation. A moderate, positive relationship was found between the number of maternal utterances and the total number of infant vocalizations, $r(48) = .35, p = .01$ and positive infant vocalizations, $r(48) = .33, p = .02$. There was no correlation between maternal utterances and negative infant vocalizations, $r(48) = .17, p = .25$.

Pointing. Pointing is an important joint attention behavior. For the mother, a point can be used to communicate or highlight information to the infant. Pointing is also a simple way for the
infant to interact with the mother during the early stages of language development. Thus, the relationship between maternal and infant pointing was investigated next. There was no correlation between maternal pointing to the 3D object or 2D image and infant pointing to the 3D object or 2D image. There was also no correlation between infant pointing to the 3D object or 2D image and maternal pointing from 3D to 2D or from 2D to 3D (see Table 8).

Table 8

First order correlations between maternal pointing and infant pointing

<table>
<thead>
<tr>
<th></th>
<th>3D (Mom)</th>
<th>2D (Mom)</th>
<th>3D to 2D (Mom)</th>
<th>2D to 3D (Mom)</th>
</tr>
</thead>
<tbody>
<tr>
<td>3D Object (Infant)</td>
<td>-0.08</td>
<td>0.04</td>
<td>-0.03</td>
<td>0.06</td>
</tr>
<tr>
<td>2D Image (Infant)</td>
<td>0.10</td>
<td>0.24</td>
<td>-0.03</td>
<td>0.22</td>
</tr>
</tbody>
</table>

**Button pushes.** During the teaching task, mothers were able to decide how hands on they wanted to be in showing their infant how the demonstration stimulus worked. For example, one mother may have taken the lead and persistently demonstrated the button push whereas another mother may have let her infant engage more with the demonstration stimulus by doing more of the button pushing. Thus, I first conducted a Pearson product-moment correlation to examine whether there was a relationship between the rate of maternal button pushes per minute and the rate of infant button pushes per minute. Results revealed a moderate, negative correlation between maternal and infant button pushes, $r(48) = -0.34, p = 0.015$. The correlation was also rerun without the 2 infants found to be outliers (see infant button push section) and the moderate, negative correlation remained, $r(46) = -0.34, p = 0.018$. This relationship suggests that when mothers demonstrated the target action more, infants were pushing the button less and vice versa.

Although infants’ transfer success was identical for the 2D/3D and 3D/2D conditions, it was hypothesized that mothers and infants may interact with the demonstration stimulus
differently depending on condition. That is, teaching infants how the 2D button works (2D/3D condition) on the demonstration stimulus may have required more maternal demonstrations than demonstrating how the 3D button works (3D/2D condition) because engaging with a touch screen would be less familiar to the infant. To explore this relationship further, a 2(participant: mother, infant) x 2(condition, 2D/3D, 3D/2D) analysis of variance (ANOVA) was conducted on the rate of button pushes. The results of the ANOVA yielded no significant main effects of participant, \( F(1, 96) = 0.30, p = 0.59, \) partial \( \eta^2 = 0.003 \), or condition, \( F(1, 96) = 0.36, p = 0.55, \) partial \( \eta^2 = 0.004 \). However there was a significant participant by condition interaction, \( F(1, 96) = 11.38, p = 0.001, \) partial \( \eta^2 = 0.11 \). The rate of maternal button pushes was significantly greater on the 2D touch screen (i.e., 2D/3D condition) compared to the rate of infant button pushes on the 2D image whereas the rate of infant button pushes was significantly greater on the 3D object (i.e., 3D/2D condition) compared to the rate of maternal button pushes on the 3D object (see Table 9).

That is, consistent with my hypothesis, mothers provided more demonstrations on the more difficult 2D touch screen, whereas infants pushed the button more often on the 3D object. It should be noted that the same ANOVA was rerun excluding the 2 infant outliers and although the average rate of infant button pushes decreased (see Table 9), the overall pattern of results remained the same; there were no main effects of participant or condition and the participant by condition interaction was still significant, \( F(1, 94) = 9.34, p = 0.003, \) partial \( \eta^2 = 0.09 \).
Table 9

*Rate of maternal and infant button pushes by condition*

<table>
<thead>
<tr>
<th>PARTICIPANT</th>
<th>2D/3D (n=25)</th>
<th>3D/2D (n=25)</th>
<th>TOTAL (n=50)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>M</td>
<td>SD</td>
<td>M</td>
</tr>
<tr>
<td>Mother</td>
<td>3.44</td>
<td>2.22</td>
<td>2.28</td>
</tr>
<tr>
<td>Infant</td>
<td>1.81</td>
<td>1.76</td>
<td>3.47</td>
</tr>
<tr>
<td>Mother + Infant</td>
<td>2.63</td>
<td>2.15</td>
<td>2.88</td>
</tr>
<tr>
<td>Infant (without outliers)</td>
<td>1.81</td>
<td>1.76</td>
<td>2.87</td>
</tr>
</tbody>
</table>

*Note.* The results of the ANOVA did not change when the 2 infant (n = 23) outliers were removed from the 3D/2D condition (n = 23).

Latency to touch. At the beginning of the teaching task, the mother-infant dyad was presented with both the 3D object and 2D touch screen image at the same time. The mother had full control over whether she interacted with or directed her infants’ attention to the 3D object or 2D touch screen image first. It was possible for the mother to engage with the object or image through verbal input and pointing, without actually ever touching the object or image. This was demonstrated by the fact that 36% of the mothers (n = 18) never touched the test stimulus. Sixty-one percent of those mothers (n = 11) had infants who were still successful on the task. Interestingly, 83% of the mothers (n = 15) who did not touch the test stimulus were in the 3D/2D condition. All mothers touched the demonstration stimulus. On the other hand, all but one infant touched the demonstration stimulus and all infants touched the test stimulus.

Another important area to consider was the relationship between when the mother and infant first touched the 3D object and 2D image. Pearson product-moment correlations were
conducted between the mother and infant latency to touch the 3D object and 2D image. There was a moderate, positive correlation between the mother’s first touch of the 3D object and the infant’s first touch of the 3D object and the mothers’ first touch of the 2D image and infant’s first touch of the 2D image (see Table 10). There was a moderate, negative correlation between the mother’s first touch of the 3D object and the mother’s first touch of the 2D image. There was no correlation between when the infant first touched the 3D object and when the infant first touched the 2D image (see Table 10). There was also no correlation between when the mother first touched the 3D object and the infant first touched the 2D image (or vice versa).

Table 10

*First order correlations between mother and infant latency to touch the 3D object and 2D image*

<table>
<thead>
<tr>
<th></th>
<th>3D (Mom)</th>
<th>2D (Mom)</th>
<th>3D Object (Infant)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2D Image (Mom)</td>
<td>-.40</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>3D Object (Infant)</td>
<td>.34</td>
<td>-.30</td>
<td>-</td>
</tr>
<tr>
<td>2D Image (Infant)</td>
<td>-.28</td>
<td>.41</td>
<td>-.22</td>
</tr>
</tbody>
</table>

*a n = 32. b n = 47. c n = 46. d n = 35. e n = 34. f n = 49.*

*Correlation is significant at the 0.05 level (2-tailed).*

Given the findings from the correlations between latency to first touch the 3D object and 2D image, I subsequently examined whether the mother and infant latency to touch differed by condition. For example, in the 3D/2D condition, mothers may have been more likely to touch the 3D object first since that was designated as the “demonstration tool” whereas a mother assigned to the 2D/3D condition may have focused on the 2D image first. Thus, a series of independent sample t-tests were conducted to compare whether there were differences in mother and infant latency to touch for each condition. The results revealed a significant difference in latency to touch for each condition. Mothers in the 3D/2D group touched the 3D object significantly
quicker than mothers in the 2D/3D group, $t(21) = 6.14, p = .00$. Alternatively, mothers in the 2D/3D group touched the 2D image significantly quicker than mothers in the 3D/2D group, $t(10) = 4.82, p = .001$ (see Table 11). The same pattern of results emerged for the infants. Infants’ latency to touch the 3D object was significantly faster in the 3D/2D condition compared to the 2D/3D condition, $t(25) = 3.82, p = .001$. Infants’ latency to touch the 2D image was significantly faster in the 2D/3D condition compared to the 3D/2D condition, $t(32) = 3.27, p = .003$ (see Table 11).

Table 11

Mother and infant latency (seconds) to touch 3D object and 2D image by condition

<table>
<thead>
<tr>
<th>LATENCY TO TOUCH</th>
<th>CONDITION</th>
<th>2D/3D</th>
<th>3D/2D</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>M</td>
<td>SD</td>
<td>n</td>
</tr>
<tr>
<td>3D Object (Mom)</td>
<td>81.69a</td>
<td>58.02</td>
<td>22</td>
</tr>
<tr>
<td>2D Image (Mom)</td>
<td>14.78a</td>
<td>13.07</td>
<td>25</td>
</tr>
<tr>
<td>3D Object (Infant)</td>
<td>55.41a</td>
<td>56.40</td>
<td>25</td>
</tr>
<tr>
<td>2D Image (Infant)</td>
<td>20.60a</td>
<td>21.74</td>
<td>24</td>
</tr>
</tbody>
</table>

Note. Latency to touch is significantly different by condition when the means are followed by different letters, all $p$’s < .01.

Taken together, these findings show that both mothers and infants were more likely to touch the demonstration stimulus first and that they spent some time with the demonstration stimulus before touching the test stimulus. The positive relationship between the mother’s and infant’s first touch of the 3D object and the relationship between the mother’s and infant’s first touch of the 2D image is predicted by stimulus enhancement (Want & Harris, 2002). In this
social learning process, the infants’ initial interest in either the object or image would be increased following the initial touch of the same object or image by the mother.

**Mother-Infant Dyad – Global Ratings**

The previous sections have provided a rich description of the behaviors mothers and infants exhibit during a transfer of learning task. The findings have indicated that in a middle to high SES sample, mothers use similar amounts and types of verbal and nonverbal (e.g., pointing, demonstrations) behaviors to teach their infants about the relationship between a 2D image and 3D object, irrespective of transfer success. Infants responded to this teaching situation with similar amounts and types of verbal and nonverbal behaviors. As such, no strong predictor of transfer success has emerged in the data thus far. In this section, global rating scales are used to take a more in depth look at the reciprocal relationship between mother and infant via measures of emotional responsiveness and maternal structuring and how they relate to successful infant transfer.

**Emotional responsiveness.** There were four emotional responsiveness measures: turn taking, shared focus, maternal warmth, and infant responsiveness; each was coded on a 5-point scale. The scores on the 4 measures were also summed to obtain an overall measure of emotional responsiveness.

A one-way between groups MANOVA was conducted to investigate whether there were differences in the dyad’s emotional responsiveness for infants who successfully transferred and infants who did not. Five dependent variables were included: shared focus, turn taking, maternal warmth, child involvement, and overall emotional responsiveness. The MANOVA yielded a significant main effect of infant success, $F(4, 43) = 7.54, p = .00$, partial $\eta^2 = .41$. 
Follow-up univariate ANOVAs were performed to examine which measures of emotional responsiveness were significantly different for the transfer and no transfer groups. Results revealed that infants who successfully transferred were participants in mother-infant dyads who had significantly higher levels of emotional responsiveness for all five measures (see Table 12). Infants who transferred maintained significantly more shared focus with their mothers, $F(1, 46) = 16.32, p = .00$, partial $\eta^2 = .26$ compared to infants who did not transfer. Mothers and infants engaged in significantly more turn taking for the infant transfer groups compared to non infant transfer groups, $F(1, 46) = 8.83, p = .005$, partial $\eta^2 = .16$. Mothers, whose infants transferred, were rated significantly higher on warmth and sensitivity toward infants compared to mothers whose infants who did not transfer, $F(1, 46) = 6.0, p = .02$, partial $\eta^2 = .12$. Infant involvement in the task was significantly higher, $F(1, 46) = 28.38, p = .00$, partial $\eta^2 = .38$ for infants who transferred compared to infants who did not transfer. Finally, infants who successfully transferred were participants in mother-infant dyads who had significantly higher overall levels of emotional responsiveness, $F(1, 46) = 16.27, p = .00$, partial $\eta^2 = .26$. Although there were significant differences in the amount of emotional responsiveness across transfer groups, it is important to note that the average level of responsiveness was at least a “3” for each individual measure for the no infant transfer groups, indicating that these types of emotional responsiveness were occurring during approximately half of the session time (see Table 12).
Table 12

Mean emotional responsiveness ratings by infant transfer success

<table>
<thead>
<tr>
<th>EMOTIONAL RESPONSIVENESS</th>
<th>TRANSFER SUCCESS</th>
<th></th>
<th></th>
<th></th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>TRANSFER SUCCESS</td>
<td>INFANT TRANSFER (n = 30)</td>
<td>NO INFANT TRANSFER (n=18)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>M</td>
<td>SD</td>
<td>M</td>
<td>SD</td>
<td></td>
</tr>
<tr>
<td>Shared focus</td>
<td>4.27a</td>
<td>0.87</td>
<td>3.17b</td>
<td>0.99</td>
<td>0.000</td>
</tr>
<tr>
<td>Turn taking</td>
<td>3.93a</td>
<td>0.94</td>
<td>3.11b</td>
<td>0.90</td>
<td>0.005</td>
</tr>
<tr>
<td>Maternal warmth</td>
<td>4.40a</td>
<td>0.81</td>
<td>3.83b</td>
<td>0.71</td>
<td>0.018</td>
</tr>
<tr>
<td>Infant involvement</td>
<td>4.37a</td>
<td>0.72</td>
<td>3.11b</td>
<td>0.90</td>
<td>0.000</td>
</tr>
<tr>
<td>Overall</td>
<td>16.97a</td>
<td>3.01</td>
<td>13.22b</td>
<td>3.28</td>
<td>0.000</td>
</tr>
</tbody>
</table>

Note. Means in a row that do not share the same subscripts differ significantly, p < .01, except for maternal warmth, p < .05.

Maternal structuring. Maternal structuring was divided into 4 categories: teaching style, teaching effectiveness, teaching amount, and nonverbal teaching.

A series of chi-square analyses were conducted to examine whether each category of maternal structuring was related to infant transfer success. A 2(teaching style: repetitive, diverse) x 2(infant success: transfer, no transfer) chi-square revealed a trend for an effect of teaching style, $\chi^2(1, N = 48) = 2.82, p = .09$. All but three infants of mothers who used diverse teaching strategies were successful on the task, whereas infants whose mother used a repetitive teaching style were just as likely to transfer as they were to not transfer (see Table 13).

A 2(amount of structure: too little/too much, optimal) x 2(infant success: transfer, no transfer) chi-square revealed a significant effect of teaching amount, $\chi^2(1, N = 48) = 5.04, p = .03$. Infants were significantly more likely to succeed in transferring when their mother provided
an optimal amount of structure by attempting to organize their infants’ attention, motivation, and interest in the task than mothers who provided too little or too much structure (see Table 13).

A 2(teaching effectiveness: not successful, successful) x 2(infant success: transfer, no transfer) chi-square revealed a significant effect of teaching amount, $\chi^2(1, N = 48) = 17.57, p = .00$. Infants were significantly more likely to successfully transfer when their mother was successful in organizing their attention, motivation, and interest in the task than mothers who were not successful in doing so (see Table 13).

A 2(nonverbal teaching: limited, good) x 2(infant success: transfer, no transfer) chi-square revealed no effect of nonverbal teaching, $\chi^2(1, N = 48) = .00, p = 1.00$. Infant success on the task was not dependent on the amount of nonverbal strategies (e.g., placing the 3D object next to the 2D image to highlight their similarity) exploited by the mother (see Table 13).
Table 13

*Chi-square analyses for maternal structuring by infant transfer success*

<table>
<thead>
<tr>
<th>MATERNAL STRUCTURING</th>
<th>TRANSFER SUCCESS</th>
<th># of Mothers</th>
<th># of Mothers</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>INFANT TRANSFER</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>NO INFANT TRANSFER</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TEACHING STYLE</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Repetitive</td>
<td>18</td>
<td>15</td>
<td></td>
<td>.09</td>
</tr>
<tr>
<td>Diverse</td>
<td>12</td>
<td>3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>TEACHING AMOUNT</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Too Little/Too Much</td>
<td>10</td>
<td>12</td>
<td></td>
<td>.03</td>
</tr>
<tr>
<td>Good Amount</td>
<td>20</td>
<td>6</td>
<td></td>
<td></td>
</tr>
<tr>
<td>TEACHING EFFECTIVENESS</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Not Successful</td>
<td>5</td>
<td>14</td>
<td></td>
<td>.00</td>
</tr>
<tr>
<td>Successful</td>
<td>25</td>
<td>4</td>
<td></td>
<td></td>
</tr>
<tr>
<td>NONVERBAL TEACHING</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Limited Amount</td>
<td>5</td>
<td>3</td>
<td></td>
<td>1.00</td>
</tr>
<tr>
<td>Good Amount</td>
<td>25</td>
<td>15</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Note. *Pearson chi-square statistic reported for all measures except nonverbal teaching which had 1 cell with an expected count less than 5; Fisher’s exact reported for nonverbal teaching.*

**Emotional responsiveness and maternal structuring.** The two previous sections have illustrated differences in the emotional responsiveness and maternal structuring for infants who transferred and infants who did not transfer. The next step was to examine how the emotional responsiveness measures and maternal structuring measures were related to each other both within (e.g., is high maternal warmth related to consistent turn taking?) and across (e.g., are high levels of shared focus related to teaching effectiveness?) the measures. Infant activity level was
also included in the correlations. In examining emotional responsiveness, there were strong, positive correlations between all measures: turn taking, shared focus, maternal warmth, and infant involvement (see Table 14). For the maternal structuring measures, there was a moderate, positive relationship between teaching style and teaching effectiveness. For amount of structure, there was a strong, positive correlation with teaching style and teaching effectiveness, and a moderate, positive correlation with nonverbal teaching. There was no correlation between nonverbal teaching and teaching style or teaching effectiveness (see Table 14).

In examining the relationship between the emotional responsiveness and maternal structuring measures, strong, positive correlations were found between teaching style and turn taking and shared focus, and moderate, positive correlations were found between teaching style and maternal warmth and infant involvement. There were strong, positive correlations between teaching effectiveness and amount of structure and all measures of emotional responsiveness. There were no correlations between nonverbal teaching and any of the emotional responsiveness measures (see Table 14). Lastly, in considering the relationship with infant activity level, there were moderate, negative correlations between infant activity level and teaching style, teaching effectiveness, and amount of structure, but no correlation with nonverbal teaching. There were strong, negative correlations between infant activity level and all measures of emotional responsiveness (see Table 14).
Table 14

*First order correlations between maternal structuring, emotional responsiveness and infant activity level variables*

<table>
<thead>
<tr>
<th></th>
<th>Teaching Style</th>
<th>Teaching Effectiveness</th>
<th>Amt of Structure</th>
<th>Nonverbal Teaching</th>
<th>TT</th>
<th>SF</th>
<th>MW</th>
<th>II</th>
</tr>
</thead>
<tbody>
<tr>
<td>Teaching Effectiveness</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Amount of Structure</td>
<td>.36*</td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Nonverbal Teaching</td>
<td>.20</td>
<td>.24</td>
<td>.31*</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Turn Taking (TT)</td>
<td>.54**</td>
<td>.67**</td>
<td>.71**</td>
<td>.25</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Shared Focus (SF)</td>
<td>.50**</td>
<td>.82**</td>
<td>.72**</td>
<td>.17</td>
<td>.88**</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Maternal Warmth (MW)</td>
<td>.44**</td>
<td>.62**</td>
<td>.60**</td>
<td>.21</td>
<td>.78**</td>
<td>.73**</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Infant Involvement (II)</td>
<td>.40**</td>
<td>.74**</td>
<td>.58**</td>
<td>.07</td>
<td>.79**</td>
<td>.89**</td>
<td>.67**</td>
<td></td>
</tr>
<tr>
<td>Infant Activity Level</td>
<td>-.29*</td>
<td>-.51**</td>
<td>-.33*</td>
<td>-.25</td>
<td>-.65**</td>
<td>-.69**</td>
<td>-.60**</td>
<td>-.72**</td>
</tr>
</tbody>
</table>

*Note. Categorical variables of teaching style (0 = repetitive, 1 = diverse), amount of structure (0 = too little/too much, 1 = optimal amount) and teaching effectiveness (0 = not successful, 1 = successful) were dummy coded.*

*Correlation is significant at the 0.05 level (2-tailed). **Correlation is significant at the 0.01 level (2-tailed).*

**Cluster analysis.** For the present teaching task, I was interested in identifying whether mother-infant dyads exhibited different patterns of behavior based on emotional responsiveness, maternal teaching, and maternal verbal input. K-means cluster analysis is a good technique to use to detect underlying structures in a dataset (Easterbrooks et al., 2005). It also classifies cases into subgroups based on a set of specific attributes.

The total emotional responsiveness score, proportion of new maternal verbal input, and maternal structuring (effectiveness and amount) were chosen to enter into the cluster analysis for two reasons. First, the individual measures of emotional responsiveness were strongly correlated with each other, so using the overall score provided a good representation of the individual measures. The measures were also strongly correlated with the proportion of new information.
and maternal structuring measures of teaching effectiveness and amount of structure. Thus, these two measures were added together to create an overall structuring score (range 2 to 4). Second, prior research has shown positive associations between mothers who respond and adapt to their infants’ behaviors and vary their verbal input to match their infants’ focus of attention and later cognitive development (e.g., DeLoache & DeMendoza, 1987; Farrant & Reese, 2000; Flynn & Masur, 2007; Rogoff, 1990). It was predicted that this high level of scaffolding would also benefit infants in a difficult transfer of learning task.

The included measures were only scored for 48 of the mother-infant dyads in the sample. Thus, I conducted the cluster analysis using a 2-cluster model, as a sample size of 48 is sufficient for classifying cases into 2 clusters (Stata Manual, 2007). I named cluster 1 \((n = 31)\), with maternal teaching that was well-structured, a high proportion of new maternal verbal input, and high overall levels of emotional responsiveness as $high\ scaffold$. I named cluster 2, with maternal teaching that was only moderately structured, a moderate proportion of new maternal verbal input, and moderate levels of emotional responsiveness as $medium\ scaffold$. Table 15 shows the means for maternal teaching, the proportion of diverse information, and emotional responsiveness as a function of the cluster.
Table 15

*Maternal structuring, proportion of new maternal verbal input and overall emotional responsiveness as a function of scaffolding level*

<table>
<thead>
<tr>
<th>SCAFFOLDING LEVEL</th>
<th>HIGH SCAFFOLD (n=31)</th>
<th>M</th>
<th>SD</th>
<th>M</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maternal Structuring</td>
<td>3.68</td>
<td>0.60</td>
<td>2.18</td>
<td>0.53</td>
<td></td>
</tr>
<tr>
<td>Prop. New Maternal Verbal Input</td>
<td>0.66</td>
<td>0.09</td>
<td>0.54</td>
<td>0.11</td>
<td></td>
</tr>
<tr>
<td>Overall Emotional Responsiveness</td>
<td>17.77</td>
<td>1.80</td>
<td>11.53</td>
<td>2.21</td>
<td></td>
</tr>
</tbody>
</table>

**Predictors of infant transfer.** Throughout the results, infant transfer has been used as an independent variable to describe the differences in mother, infant, and mother-infant behaviors. However, one of the main goals of the task was to examine what specific elements of the task itself or mother-infant behaviors may *predict* infant transfer success. Because infants could either succeed on the task or not, logistic regression was used for this analysis. The dependent variable was dichotomous; with ‘1’ indicating infant success on the transfer task and ‘0’ indicating the infant was not successful on the transfer task. The independent variables included were mothers’ classification as high or medium scaffold, infant activity level, stimulus (bus or cow), and condition (2D/3D, 3D/2D); all variables were dichotomous. Infant activity level was included because a chi-square analysis previously revealed that low activity level infants were significantly more likely to successfully transfer than moderate activity level infants. Stimulus was included because a chi-square analysis previously showed that infants tested with the bus were more likely to succeed than infants tested with the cow. Condition was included in the final
model to confirm that infants could succeed on a transfer of learning task regardless of the
direction of teaching.

The results of the logistic regression revealed that only the level of scaffolding was a
significant predictor of infant success on the transfer task (see Table 16). Infant activity level,
stimulus, and condition were not significant predictors of infant transfer success. The significant
odds ratio of 22.09 ($p = 0.01$) for scaffolding level indicates that infants were 22 times more
likely to succeed on the task if they were in a high scaffold dyad, holding all other variables
constant (see Table 16).

Table 16

Results from logistic regression analysis of infant transfer success

<table>
<thead>
<tr>
<th></th>
<th>B</th>
<th>S.E.</th>
<th>p</th>
<th>Odds Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scaffold group</td>
<td>3.10</td>
<td>1.22</td>
<td>.01</td>
<td>22.09</td>
</tr>
<tr>
<td>Activity level</td>
<td>-0.57</td>
<td>1.24</td>
<td>.65</td>
<td>0.57</td>
</tr>
<tr>
<td>Condition</td>
<td>-.43</td>
<td>0.80</td>
<td>.59</td>
<td>0.65</td>
</tr>
<tr>
<td>Stimulus</td>
<td>1.20</td>
<td>0.78</td>
<td>.13</td>
<td>3.31</td>
</tr>
</tbody>
</table>

Note. B: unstandardized estimates; S.E.: standard error

The accuracy of the prediction performed by the logistic regression was also evaluated
using a classification table. The classification table shows that approximately 87% of infants who
were predicted to be successful on the transfer task were in fact successful. Approximately 72%
of infants who were predicted to be unsuccessful were not successful (see Table 17).
Table 17

Classification table for logistic regression on infant transfer success

<table>
<thead>
<tr>
<th>Observed Infant Transfer</th>
<th>Predicted Infant Transfer</th>
<th>% Correct</th>
</tr>
</thead>
<tbody>
<tr>
<td>No</td>
<td>13</td>
<td>5</td>
</tr>
<tr>
<td>Yes</td>
<td>4</td>
<td>26</td>
</tr>
<tr>
<td>Total</td>
<td>81.3</td>
<td></td>
</tr>
</tbody>
</table>

A standard linear regression analysis was also conducted with the same independent variables (scaffold group, infant activity level, condition, and stimulus) and infant latency to success (from the start of the session) as the continuous, outcome variable. Infants who did not succeed on the task were given a latency of 300 seconds, the maximum time allowed to complete the task. Initial collinearity diagnostics indicated that all Variance Inflation Factors were \( \leq 2 \). The overall model for infant latency to success was significant, \( F(4, 43) = 4.65, p = .003, R = .55, R^2 = .30 \). The pattern of results was identical to those found in the logistic regression analysis; only scaffold group was a significant predictor of infant latency to success (see Table 18).

Table 18

Factors that predict infant latency to transfer success

<table>
<thead>
<tr>
<th>Predictors</th>
<th>Unstandardized Coefficients</th>
<th>Standardized Coefficients</th>
<th>t</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Beta</td>
<td>S.E.</td>
<td>Beta</td>
</tr>
<tr>
<td>Scaffold group</td>
<td>83.74</td>
<td>33.46</td>
<td>0.45*</td>
</tr>
<tr>
<td>Activity level</td>
<td>14.77</td>
<td>32.44</td>
<td>0.08</td>
</tr>
<tr>
<td>Condition</td>
<td>-11.60</td>
<td>22.77</td>
<td>-0.07</td>
</tr>
<tr>
<td>Stimulus</td>
<td>18.07</td>
<td>24.01</td>
<td>0.10</td>
</tr>
</tbody>
</table>

\( *p < .05. \)
Discussion

The present work examined infants’ transfer of learning between a 2D image and 3D object in the context of a novel maternal teaching task. Results revealed that a moderately high percentage of infants transferred between 2D and 3D; however performance was well below ceiling. Consistent with findings from Experiment 2, infant receptive and productive vocabulary (as measured by the MCDI) was not related to transfer success. I was also able to provide a detailed account of infant and maternal behavior in a transfer of learning, teaching task. Infant vocalizations, amount of pointing, and engagement with the button on the demonstration stimulus did not vary based on whether the infants succeeded on the task. Similarly, mothers’ specific types of verbal input and nonverbal teaching strategies, including modeling, did not vary as a function of infant transfer. Scaffolding level, as measured by emotional responsiveness, maternal structuring, and diversity of new information provided by the mother, was the only significant predictor of infant transfer success.

Infant Transfer of Learning between 2D and 3D

In the presence of a social partner, infants successfully transferred between 2D and 3D well above the transfer levels reported in the experimental version of the touch screen task (see Experiments 1 and 2) but notably below within-dimension (3D/3D or 2D/2D) performance levels (see Experiment 1). Transfer of learning was identical across condition, that is, infants were just as successful when mothers were asked to teach from 3D to 2D as they were when mothers taught from 2D to 3D. This is consistent with findings from Experiment 1, but not Experiment 2, in which the addition of language cues decreased performance from 3D to 2D. Overall, mothers were able to enhance transfer of learning in this novel teaching context. There are, however,
several caveats to making comparisons between the semi-naturalistic and experimental versions of the task. These will be addressed in the limitations section.

**Maternal Verbal & Nonverbal Input**

Overall, the frequency and rate of behaviors were uniform across the mothers of infants who successfully transferred and mothers of infants who did not successfully transfer. Mothers did not differ in the type of verbal input provided, amount of pointing, or button push demonstrations as a function of infant transfer success. In general, and perhaps not surprisingly, the amount of maternal modeling was high compared to studies with older children (e.g., Laosa, 1980). The rate of maternal modeling, however, did vary by condition. Mothers performed more demonstrations when the demonstration tool was the 2D touch screen image (2D/3D condition) compared to when it was a 3D object (3D/2D condition). Infants did the reverse, pushing the button more often in the 3D/2D condition compared to the 2D/3D condition. Mothers’ behavior is consistent with Vygotskian theory which suggests that the less knowledgeable an adult believes their child to be, the more support they provide. Mothers adapted their demonstrations to meet the experience level of their infants.

Contrary to my hypothesis, the content of mother’s verbal teaching did not vary for infants who transferred and those who did not transfer. The largest proportions of maternal utterances were questions and labels (during the first 2 minutes of the task). This finding is in line with prior research on mother-infant interactions during book reading (DeLoache & DeMendoza, 1987) and coviewing of infant-directed programming (Barr et al., 2008; Fidler et al., 2010). One important distinction between the present teaching task and coviewing studies is the relationship between maternal verbal input and infant outcomes.
Barr and colleagues (2008) found that 12- to 18-month-old infants of mothers who provided a high level of scaffolding in the form of questions and labels and descriptions looked longer and responded more to the programming compared to infants of mothers who provided lower levels of scaffolding. Fidler et al. (2010) replicated this finding with infant looking in younger age groups. This is in stark contrast to the high level of questions and labels provided by all mothers in the teaching task and lack of a relationship with infant transfer. Considering the nature of the task and demographics of the sample may help elucidate these discrepancies.

Although mother-infant dyads in both the teaching task and coviewing studies (Barr et al., 2008; Fidler et al., 2010) were all from middle to high SES, well-educated backgrounds, only the mothers in the present study were specifically asked to treat the media context as a teaching situation. In a coviewing context, mothers might be less inclined to direct their infants’ attention to a television screen. Given these differences, it is not surprising that mothers used high verbal scaffold strategies when placed in a situation in which they were forced to teach.

One unpredicted finding was the rare occurrence of verbal strategy use by the mothers. In particular, most mothers provided a verbal matching cue on at least one occasion (e.g., “this cow moos [2D] and this cow moos [3D]”), but half of the mothers did so on fewer than 5 occasions. There was also a positive relationship between the amount of verbal matching cues and maternal pointing between 2D and 3D (or vice versa); but this type of pointing was not used by most of the mothers. Given the correspondence between the 3D object and 2D image, it was hypothesized that mothers would readily adopt these strategies. Why did most mothers not capitalize on the side-by-side presentation of the 2D touch screen image and 3D object to accentuate their similarities? One possibility is that the perceptual similarity between the 2D
The image and 3D object was an obvious correspondence to the mother and because it was obvious to the mother she may have assumed it was also obvious to the child.

Mothers also rarely explained the cause and effect relationship between pushing the button and making the sound and infrequently highlighted the location of the button on the demonstration stimulus. These strategies could have occurred infrequently because the mother might have considered the task too difficult or these to be ineffective teaching strategies for a 15-month-old.

The proportion of “new” information that mothers provided was the only aspect of maternal verbal input that was significantly different for the transfer and no transfer groups. Mothers of successful infants would either make a statement (e.g., “this is a cow”) and immediately elaborate it on it (e.g., “the cow says moo”) or provide new information (e.g., “you can push his button”). In comparison, mothers of infants who did not transfer did this less frequently, often providing the same piece of information multiple times in a row (e.g., “this is a cow” said three times). Although all mothers did revert back to providing some of the same verbal information that they used earlier in the task, the mothers of infants who transferred were not as repetitive in the sequencing of their verbal input. The proportion of new information provided by mothers was also positively related to their emotional responsiveness. It is possible that mothers who varied their verbal input more frequently did so because they were better attuned to their infants’ actions and interest in the task.

This difference in the style of maternal input has also been demonstrated in studies examining mothers reminiscing with their preschool-aged children about the past (Fivush & Fromhoff, 1988; Hudson, 1990; Reese & Fivush, 1993). Mothers differ in the structure of their discussions about the past with their children, with some mothers being classified as elaborative
and others as repetitive (e.g., Reese & Fivush, 1993). Furthermore, Hudson (1990) found that children were more engaged and responded more frequently to verbal requests from an experimenter when their mothers were highly elaborative with them compared to children of more repetitive mothers. On average, mothers provided new information more than 50% of the time, regardless of infant transfer success in the touch screen task. This finding is not surprising for mothers from middle to high SES, well-educated backgrounds in a teaching situation.

**Emotional Responsiveness & Maternal Structuring**

It was difficult to distinguish a mother of an infant who successfully transferred from a mother of an infant who did not successfully transfer based on verbal and nonverbal input alone. However, *how* mothers utilized these behaviors in relation to their infants did differ for the transfer and no transfer groups. Successful mother-infant dyads displayed higher levels of emotional responsiveness (e.g., turn taking) compared to unsuccessful mother-infant dyads. This was true for all measures of emotional responsiveness. There was an ongoing synchrony in the interactions between mothers and the infants who transferred. Mothers displayed greater sensitivity to the interests and focus of her infant through her verbal and nonverbal input. Thus, infants might have benefited more from the verbal and nonverbal input of mothers who timed their behaviors to ensure they had their infants’ attention (Flynn & Masur, 2007; Tamis-LeMonda et al., 2001). Maternal responsiveness consistently predicts future cognitive, language, and social outcomes (Bornstein, 1989, Bornstein et al., 2008; Kaplan et al., 2001; Tamis-LeMonda et al., 2001). In the present study, a positive relationship was found with responsiveness when examining an immediate infant outcome – transfer of learning.

To my knowledge, there has been little research conducted on the relationship between emotional responsiveness and an immediate infant outcome during a novel teaching task. Ayoun
(1998) found that the level of maternal responsiveness exhibited by mothers to their 11-month-olds during a free play session was significantly related to how well infants performed on a hidden object and contingency-based touch screen task. Ayoun proposed that infants who have been nurtured in predictable, responsive relationships with their caregivers are more likely to detect relationships between actions and goals in other contexts. Although Ayoun’s conclusions were speculative, they offer support for the positive relationship found between emotional responsiveness and infant transfer of learning in the teaching task.

Maternal teaching was also related to success; mothers who provided optimal levels of structure and were effective in their structuring of the situation were more likely to have their infants successfully transfer. Mothers’ use of appropriate amounts of guidance and structure during the task and its relationship with infant outcomes supports Vygotskian theory and prior research showing a positive relationship between supportive parent-child interactions and young children’s cognitive development (e.g., Dodici et al., 2003; Farrant & Reese, 2000; Rogoff, 1990). The vast majority of mothers consistently used nonverbal strategies (e.g., primarily pointing, but also placing the 3D object next to the 2D image to highlight their similarity) throughout the task.

Importantly, the combination of emotional responsiveness, amount and effectiveness of maternal structuring and the proportion of new information provided clearly distinguished successful mother-infant dyads from unsuccessful dyads when a cluster analysis was conducted. High scaffold dyads had higher amounts for each of these measures compared to medium scaffold mothers. Furthermore, infants in high scaffold dyads were 22 times more likely to successfully transfer than infants in the medium scaffold group. These findings suggest that a
responsive social partner plays an important role in infant transfer of learning between 2D and 3D. This has implications for how infants should engage with 2D sources for learning to occur.

Limitations

There were two overall limitations of the touch screen teaching task that also need to be addressed: task complexity and age of the infants. The use of a one-step action may have been problematic because unintentional transfer success is more likely to occur. Admittedly, there were a few instances in which it is possible the infant accidentally pushed the button on the test stimulus. Due to the age of the infants, however, it is impossible to know their intentions. This task was also restricted to 15- and 16-month-old infants so the findings may not be generalizable to other age groups. Moreover, the types of teaching strategies that mothers employ would be predicted to change with age. A multi-step touch screen task is currently being developed for use with a large age range (18- to 42-month-olds) to advance the current procedure in order to gain a more comprehensive understanding of transfer of learning between 2D and 3D in young children (Dickerson, Zack, Barr, & Gerhardstein, 2010).

It is also important to note a few limitations to the responsiveness and teaching measures used in this task. Although responsiveness and structuring have been assessed in other studies using a 5 minute task (e.g., Easterbrooks et al. 2005), it is still a short time period to fully assess these global ratings. For example, Biringen et al. (2005) found attachment relationships between kindergarteners and their mothers were more strongly related to emotional availability measures as session length increased. In this sample, only half of the mothers were still teaching during the fourth minute of the task.

Another potential limitation is that the emotional responsiveness and maternal structuring measures were subjective, and the raters could not be blind to infant success on the task. This
was due to noticeable variations in the session length - many of the infants who succeeded completed the task in less than 5 minutes time. Infant success on the task was also part of the session so the raters viewed this or the 5 minute mark as their stopping point. Sequential analysis will be performed in the future to quantify some of the aspects of responsiveness viewed in the task. Sequential analysis techniques can be used to analyze the length and number of bouts of turn taking between mothers and infants. More specifically, sequential analysis can be used to examine how mothers responded to frequent infant behaviors such as pointing. It is predicted that mothers rated high on responsiveness will be more likely to follow their infant’s lead.

There are also caveats to comparing this semi-naturalistic teaching task with experimental versions of the touch screen task. First, mother-infant dyads were given 5 minutes to complete the teaching task whereas infants in the experimental studies had 30 seconds from their first touch of the test stimulus to succeed in pushing the button. It is possible that transfer performance would have been higher in the experimental conditions had the session length been increased. If similar criteria were applied to the teaching task, only 14 infants (28%) would have successfully transferred within one minute from their first touch of the test stimulus. This “new” criteria would make it impossible to examine the role of maternal teaching throughout the session.

Second, there was only one set of stimuli (cow or bus) used in the teaching task. In comparison, infants viewed demonstrations on two different objects or images (cow or duck and bus or fire truck) prior to test in Experiments 1 and 2. Lower transfer levels in the experimental conditions might be partially attributed to the additional cognitive load placed on the infant by including 2 stimuli; however the inclusion of 2 stimuli did not impact performance in the within-dimension conditions (see Experiment 1). A simple follow-up experiment would be to replicate
the original transfer procedure but test children with only one stimulus to examine whether
transfer performance increases. There is one additional, and unexpected finding to note regarding
the stimuli. Infants tested with the bus succeeded more often than infants tested with the cow;
although this did not predict infant transfer success. This finding is not in line with the touch
screen experimental studies (see Experiments 1 and 2) in which no stimuli differences were
found. It is unclear from the data why this occurred.

Third, the infant’s mother replaced the experimenter, acting as the ‘demonstrator’ in the
present study whereas an unfamiliar experimenter performed the demonstrations in the
experimental version of the task. Prior research has shown that the familiarity of the
demonstrator (mother vs. stranger) does not impact infant imitation when the demonstrator is
‘live’ (Devouche, 2004; Meltzoff & Moore, 1992) or when the demonstrator appears on video
(Seehagen & Herbert, 2010). Thus, demonstrator familiarity is an unlikely explanation for the
differences seen in transfer of learning rates between the teaching and experimental tasks.

Lastly, a fundamental difference between the teaching task and experimental studies is in
the presentation style of the 3D object and 2D touch screen image. In the teaching task, mothers
and infants were presented with the 2D touch screen image and 3D object side-by-side from the
beginning of the session. In the experimental transfer conditions, however, only the
demonstration stimulus was present when the experimenter performed the target action. The
demonstration stimulus was placed out of sight during the test. A significant limitation of prior
research examining learning from 2D is the absence of a highly-controlled context in which the
2D image and 3D object are presented side-by-side. Further empirical investigation is required to
examine whether the simultaneous presentation of an object and image will be enough to
facilitate transfer on its own.
Taking into consideration all of the modifications to the teaching task, as well as the support of a rich teaching environment, it was hypothesized that infant transfer would increase compared to transfer performance in the experimental conditions (see Experiments 1 and 2). Infant transfer was enhanced, but not for 18 infants (36%) who failed to transfer between 2D and 3D. This group was marked by lower amounts of emotional responsiveness within the dyad, maternal structuring, and diversity of new information presented by the mother, suggesting that it was not simply the nature of the task set-up that facilitated infant transfer.

**Future Directions**

A semi-naturalistic task provides a good starting point for understanding what infant transfer of learning looks like in a social context and what factors are related to transfer of learning. In future studies, specific aspects of the task that might have improved transfer can be experimentally manipulated to test their true effects. Future transfer of learning studies should examine the facilitative effects of a side-by-side presentation of the 3D object and 2D touch screen image, increasing the length of the demonstration and/or test, manipulating the amount and type of verbal and nonverbal input (e.g., pointing), and controlling the level of responsiveness provided by the mother or experimenter. For example, the language cues presented in Experiment 2 might not have facilitated transfer due to a lack of side-by-side placement of the 2D touch screen and 3D object and/or a lack of scaffolding from the experimenter. This requires further empirical investigation. Examining individual factors in experimental settings will enable researchers to pinpoint the specific factors that decrease cognitive load in young infants and enable them to transfer learning across dimensions.

Although it was important to have an immediate outcome measure in this transfer of learning task, future research should also examine infants’ ability to retain an understanding of
the relationship between 2D and 3D by testing infants after a delay. Future studies should also explore whether infant success on the touch screen task is related to infant success on other 2D-3D transfer of learning tasks. That is, is infants’ ability to transfer learning between 2D and 3D task specific, or are they able to extend their transfer knowledge to other 2D contexts such as booking reading and television coviewing.

**Conclusions & Implications**

This study builds on past research examining parent-infant interactions surrounding media use by 1) incorporating measures of verbal and nonverbal behavior with maternal teaching and responsiveness at the level of the dyad and 2) measuring their relation to an immediate infant learning outcome in the context of a novel teaching task. The present findings suggest that caregivers and mothers in particular, have an important role to play in scaffolding their infants’ learning from 2D sources. Although this task was not able to assess infant transfer of learning in the absence of high levels of verbal input, it is likely that mothers’ verbal input provided an important basis for task success. However it is not just the presence of a caregiver who verbally scaffolds that facilitates transfer. During this challenging transfer of learning task, most infants required high levels of responsiveness and structure from their mothers in order to successfully transfer.

Maternal scaffolding seems to be especially important for infants at this stage in their development. Infants’ representational, linguistic, and perceptual systems are still developing; therefore it can be challenging for them to integrate multiple sources of information on their own. This line of research has shown that infants do not easily understand the functional equivalence between a 2D image and 3D object without additional support. In particular, the results from the teaching task suggest that a caregiver can provide the support necessary to teach
their young infants about the relationship between 2D and 3D sources via the content and timing of their verbal and nonverbal cues.

Media use surveys of parents with infants show that children under the age of 2 spend between 1 to 2 hours in front of a screen each day, and the most recent survey data indicate that approximately 90% of children regularly watch media by age 2 years of age (Rideout & Hamel, 2006; Zimmerman et al., 2007). Given that exposure to 2D sources during infancy is high, the number of 2D products entering the market is increasing, and the cognitive challenge presented by such 2D sources is large (the present line of research), a significant research investment will be necessary to develop age-appropriate media for infants and young children. The learning and transfer that occurs with certain media at one particular age may not apply at another age with different type/quality of presentations. More empirical research is needed to examine the role parents play in infants’ transfer of learning between 2D and 3D sources at different ages throughout development.

The benefits of supportive maternal interactions during everyday activities such as feeding and book reading have consistently been found to be related to children’s later cognitive and social development (e.g., Farrant & Reese, 2000; Hoff, 2003; Rogoff, 1990). This is important with regard to infant learning from 2D media sources. If supportive interactions during infants’ daily activities foster positive growth and development then it is reasonable to expect maternal scaffolding to be necessary for infant learning in media contexts with more novel forms of technology.

Adults seamlessly navigate between 3D objects and 2D media tools (e.g., computer, television, iphone) in their daily activities. As such, they might not be aware of the difficulties infants face in transfer of learning across dimensions. Parents should be educated about the
challenges infants face in transferring information between 2D and 3D sources and encouraged to scaffold their infants’ interactions with 2D media sources.

In sum, transfer of learning between 2D images and 3D objects is challenging for young children. High levels of scaffolding, however, can help infants understand the functional relationship between 2D and 3D sources. This research suggests that infants require input from an engaged, responsive social partner if they are going to gain anything from technology. Media has the potential to serve as an effective teaching tool that enhances learning in young children when used in supportive parent-child contexts.
References


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APPENDIX

Examples of Diverse and Repetitive Maternal Styles

Excerpts were taken from transcripts of two mothers; one mother provided a high proportion of new information and is labeled *diverse style* and one mother had a high proportion of repetitive information and is labeled *repetitive style*. Both transcript excerpts were taken from mothers in the 3D/2D condition with the bus stimulus. The 3D or 2D in brackets indicates the stimulus that the mother was referring to for that utterance.

DIVERSE STYLE

Now (child’s name) look over here [2D]
This is really cool [2D]
Look here [2D]
See look [2D]
It’s the same picture [2D]
Can you make this one go beep beep? [2D]
You touch it [2D]
Where did you touch this one? [3D]
Right here [tandem with 3D button push]
You got it [infant just pressed 3D button]
Can you see? [2D]
What does this one do? [2D]
Is that the eyes? [2D]
Push like this eye [mother pushes 3D eye]
You’re really fascinated by this one [3D]
Look here [2D]
If you do it right here on this one [mother touches 3D button]
Look here and here [touches near 3D button then on 3D button]
Here [mom touches near 2D button]
Where can you make it go beep beep? [2D]
Try again [infant touching center of 2D screen]
You got the right place over there [infant vocalized toward 3D]
Good job [infant pressed 3D button]
What about this one? [ mother moves infant in front of 2D]
What about this one? [2D]
Oh you’re pointing that’s good [infant touching 2D with index finger]
Can you point a little closer? [2D]
Look at this [2D]
Look at that [2D]
Look at that [2D]
It’s a screen [2D]
Doesn’t that look like the other toy? [2D]
Does it look like the other toy? [2D]
It’s yellow [2D]
Looks like the other toy, doesn’t it? [2D]
Do you wanna press that button again over there? [3D]
You wanna press the button again? [3D]
Yay! [infant pressed 3D button]
Press it again [3D]
Where did it go? [3D button]
Here wanna press the button again? [3D]
Can you do it? [3D]
Can you press it again? [3D]
Yay [infant pressed 3D button]
Let’s look at the screen [2D]
Let’s look at the screen [2D]
You like the screen? [2D]
You like the screen over here? [point to 2D]
Which one you like better?
It’s big [2D]
It’s a lot bigger [2D]
I don’t think it’s going to go anywhere [infant pulling on touch screen]
Look at the little toy [point to 3D]
Doesn’t it look exactly like the one on the screen? [point to 2D]
Mmmmmmm [infant presses 3D button]
Look
Doesn’t it look like that? [point to 2D]
Looks the same thing, doesn't it? [2D]
Looks the same, doesn't it? [2D]
Yay! [infant presses 3D button]
Look at this toy [point to 2D]
It looks the same, doesn’t it? [2D]
See?
Yay! [child pressed 3D button]
Look at this toy [2D]
It looks the same, doesn’t it? [2D]
CHAPTER V: GENERAL DISCUSSION

Three studies were presented that investigated transfer of learning between 2D and 3D sources during infancy. Touch screen technology was used to examine infants’ transfer of actions in a new direction previously untested in the literature, from 3D to 2D, as well as testing from 2D to 3D as has been tested before. This body of research has shown that transfer of learning is challenging for infants, regardless of transfer direction. Each study also imparts a unique contribution to our understanding of infant learning from 2D media sources.

Experiment 1

In Experiment 1, it was demonstrated that 15-month-old infants can encode and retrieve a 2D image just as well as they can encode and retrieve a 3D object. This was evidenced by their nearly identical performance in the within-dimension conditions (2D/2D, 3D/3D). Infants were able to imitate the target action on the 2D touch screen image after viewing a demonstration on the same touch screen image. This finding helps discount perceptual encoding impoverishment as a possible explanation for deficits in infants’ transfer of learning between 2D and 3D. The perceptual impoverishment account would predict that imitating from a 2D source would be limited due to the nature of the image (e.g., smaller in size, degraded resolution, lack of depth cues), however, infants successfully imitated in the 2D/2D condition.

This finding also raised questions about the plausibility of the dual representation account for explaining difficulty in 2D-3D transfer of learning. By this account, beginning in the second year of life, infants’ recent understanding that 2D images and 3D objects are different is what makes it difficult for them to appreciate any relations between them. Thus, even in the 2D/2D condition, infants would be expected to not imitate the target action due to their understanding that 2D images cannot be acted on in the same way as 3D objects.
Infants’ performance in the within- and transfer-dimension conditions seem to be best understood within a representational flexibility framework (Hayne, 2006; see also Karmiloff-Smith, 1992 for a similar argument). Based on Hayne’s account, it is more challenging to relate information between 2D and 3D than within the same dimension (e.g., 2D to 2D or 3D to 3D) because there are fewer retrieval cues at test that match encoding conditions. Infants performed well in the within-dimension conditions because there was an exact match between the cues present during encoding and retrieval. The representational flexibility account also provided the framework for Experiment 2.

**Experiment 2**

In Experiment 2, verbal cues were added during encoding and retrieval of the transfer conditions to provide an additional match between the 2D image and 3D object. Neither novel nor simple labels facilitated infant transfer. The findings from this study further show that infants’ representational system is fragile at this stage of development. Infants’ representational system can be easily overloaded during a challenging transfer of learning task; in this study overload occurred by adding verbal labels, another symbolic cue. Thus, language cues might not have facilitated transfer of learning across dimension because of the cognitive load already placed on the infant by the complex nature of the touch screen transfer task.

**Study 3**

The third study was designed to include factors that may decrease the cognitive load associated with transfer between 2D and 3D sources. I aimed to decrease cognitive load in a number of ways: 1) by presenting the 3D object and 2D image simultaneously, 2) by increasing the length of the task, and most importantly 3) by including a social partner, the infant’s mother. First, presenting the 2D touch screen image and 3D object side-by-side should have reduced the
memory demands placed on the infants because they no longer needed to hold a representation of the demonstration object or image in mind. Second, prior research has shown that transfer from video can be facilitated by increasing either the number of demonstrations or the duration of demonstrations (e.g., Barr, Muentener, & Garcia, 2007; Barr & Wyss, 2008; Strouse & Troseth, 2008). Repetitions or increased exposure provide infants with more time to encode the object or image which in turn should increase the strength of the representation of the actions (Barr, 2010).

Lastly, having the infant’s mother teach the transfer task should have also been beneficial with regard to infants’ fragile representational system. The opportunity was there for mothers to capitalize on points 1 and 2 above, that is, highlight the similarity between the 2D image and 3D object and/or push the button on the demonstration tool as often as they saw fit. Mothers were also able to provide an array of social cues including verbal input and nonverbal information such as pointing. As a contingent social partner, mothers can tailor their behaviors to meet the moment-by-moment focus of the child while advancing the child’s understanding of the relationship or “match” between the 2D image and 3D object. Prior research has shown that social contingency can reduce the transfer deficit in studies using both live (Nielsen, 2006) and televised partners (Troseth, Saylor, & Archer, 2006). For example, Nielsen (2006) found that 18-month-old infants imitated significantly more actions with a provided tool when there was a social model compared to infants who saw a detached model.

In this study it was demonstrated that infant transfer of learning between 2D and 3D can be increased under the right circumstances. Mothers can teach their infants about the functional relationship between a 2D touch screen image and 3D real world object. Moreover, mothers were able to accomplish this and infants were able to learn about this relationship regardless of transfer direction (teaching from 3D to 2D or from 2D to 3D). The only significant predictor of
infant transfer was level of scaffolding within the dyad. Mothers who provided structure, varied their verbal input and were in sync with their infants during most of the session had infants who were significantly more likely to succeed and transfer learning between 2D and 3D.

These findings are telling for the importance of a social partner in infant learning from 2D sources. Mothers of infants who succeeded on the task did not use different types of verbal or nonverbal input to teach compared to mothers of infants who did not succeed on the task. Rather, it was how mothers used this information that was most important. Mothers who were responsive and sensitive to their infants’ behaviors and structured the task provided the support necessary for their infant to transfer. This finding is consistent with Vygotskian theory. In general, infants are unable to independently understand the functional equivalence of a 2D image and 3D object; however they can transfer learning with the instruction and feedback of a more experienced adult.

The generalizability of these findings should be treated with caution as the teaching task was conducted with a homogenous, well-educated sample. Longitudinal studies have revealed vast differences in the type and amount of verbal support low and high SES parents provide during everyday activities (Hart and Risley, 1995; Hoff, 2003; Hoff-Ginsberg, 1991). It is still unclear what patterns of maternal teaching will emerge during 2D-3D transfer of learning situations with low SES samples and how this relates to infants’ transfer abilities. This may be a particularly important future avenue of research given that media consumption tends to be higher in both low income and minority families (e.g., Mendelsohn et al., 2008).

**Learning in a Social Context**

Taking into account the social context in which learning takes place is not a new concept. Bandura (1977) postulated that observational learning is shaped through observations and
interactions with others in a social context (Bandura, 1977). In his social cognitive theory, Bandura (1986) emphasized that social interactions contribute to human thought and actions in addition to the contributions that cognitive processes play in our motivations, affect, and actions. Uzgiris (1999) also highlighted the bidirectional nature of imitation and added a developmental component to the socio-cognitive perspective. Piaget and others may have underestimated infant’s imitation ability because observations were often focused on only the behaviors of the infants as observers and not the model, which make it difficult to analyze the bidirectional relationship between model and observer (Uzgiris, 1999).

Uzgiris (1999) called for naturalistic and semi-naturalistic studies of imitation to be conducted as a requirement for being able to fully understand imitation in the context of live, face-to-face social interactions. She advocated for the adoption of an interactive perspective, one in which both the model and observer contribute. Thus, Uzgiris (1981) proposed that imitation serves two functions: cognitive understanding and a social-communicative function. As a social function, Uzgiris stated that the purpose of imitation is to communicate mutuality or sharing of understanding. This perspective can also be applied to infants’ transfer of learning. Mother-infant dyads who exhibited a synchronous relationship, demonstrating shared focus and turn taking for example, were the dyads in which infants showed transfer of learning between 2D and 3D.

**Research Summary**

Taken together, this series of studies has shown that transfer of learning is challenging for infants during a time in which their representational, linguistic, and perceptual systems are still developing. The cognitive challenge for infants is to appreciate that a 2D surface can be acted on in the same way as a 3D object. Additional encoding and retrieval cues may aide infants’
understanding of the similarity between the 2D image and 3D object but not be enough to teach their functional equivalence. With that said, a high level of scaffolding can help infants understand the functional relationship between a 2D and 3D source.

The present studies also helped rule out a number of factors that do not appear to be driving transfer of learning. The deficit in learning between 2D and 3D cannot solely be attributed to infant language comprehension or production, as neither of these was related to transfer success in Experiment 2 or the teaching task. A complete lack of social contingency that is often found in transfer of learning studies from a 2D video to real world object cannot explain the deficit as there was always a live demonstrator present in the experiments. The amount of contingency, however, is something that needs to be explored further given quality of scaffolding was the sole predictor of infant transfer success in the teaching task.

One area that has received less empirical attention is a focus on the individual differences of infants who are able to transfer learning between 2D and 3D and those infants who are not able to transfer learning across dimensions. Recall that even in Experiment 1, there were infants who transferred learning from 2D to 3D and from 3D to 2D without any additional language or social support. What is it about these specific infants that enable them to transfer?

One possible factor that I originally hoped to include, but was not able to directly examine is differences in infants’ working memory as they relate to transfer of learning. With that said, the experimental design and findings from the maternal teaching task suggest that working memory differences might not be a factor after all. Infants’ memory demands were reduced by placing the 2D touch screen and 3D object side-by-side and by only including 1 stimulus (rather than the 2 stimuli infants were tested with in Experiments 1 and 2). Over one-
third of the infants in the teaching task still did not transfer, even when the task design reduced
the likelihood of overtaxing their memory systems.

More recently, Herbert, Gross, and Hayne (2007) and Gross and Hayne (2008) examined
how infants’ prior motor experiences influence their representational flexibility. They found that
individual differences in crawling and walking ability were related to increased memory
retrieval. Gross and Hayne, for example, found that infants who reached the motor milestones of
crawling and walking by 9 and 12 months, respectively, performed better on a deferred imitation
task than infants who had not reached those motor milestones. Gross and Hayne proposed that
infants who are crawlers or walkers are exposed to new contexts and experiences in which they
need to transfer learning, thus increasing their representational flexibility.

Overall, these findings suggest that infants’ learning history and daily experiences
influence their representational flexibility. It is possible that there is a relationship between
motor and memory development that persists throughout the infancy period. Examination of
individual differences in this and other areas requires future consideration and investigation by
researchers examining transfer of learning during infancy.

**Implications**

Over the past 15 years, the media landscape for infants has changed dramatically,
resulting in an increased awareness of the public health implications of early exposure to
computers and television. Studies have demonstrated both positive and negative associations
between media exposure and attention, sleep, emotion regulation, language acquisition, and
school readiness (Christakis, Zimmerman, DiGiuseppe, & McCarty, 2004; Paik & Comstock,
1994; Thompson & Christakis, 2005; Zimmerman & Christakis, 2005; Zimmerman, Christakis,
& Meltzoff, 2007). Videos and TV programs, such as *Baby Einstein* and *Brainy Baby*, are
marketed in such a way that parents believe their babies will engage in important learning from them (Garrison & Christakis, 2005). Interactive books (e.g., LeapFrog) are also becoming increasingly popular. However, there is little research examining what or how infants learn from these sources. In particular, the role of social information in infants’ ability to transfer information between 2D and 3D has received virtually no empirical investigation.

This line of research has important implications for researchers, parents, and developers of infant media. Correspondences between 2D images and 3D objects that might seem obvious to adults are not easily understood by infants. Indeed, it appears that infants find it difficult to appreciate the functional equivalence between a 2D image and 3D object without additional support from a social partner. Parents should be encouraged to actively coview media with their infants and teach their infant about the relationship between 2D images and 3D objects to facilitate transfer of learning. In the future, researchers should ask parents what they think their infant can understand from 2D media sources. If we have a better understanding of what parents believe their infant can learn from 2D it will help researchers interpret how parents scaffold infant learning in a media context.

The results from this dissertation also have broader implications for learning in day-to-day life. Electronic and interactive products make up a large portion of children’s toys (Hirsh-Pasek & Golinkoff, 2008; Levin & Rosenquest, 2001). Recent findings, however, suggest that they may reduce the quantity and quality of parent-child interactions. For example, Wong and colleagues (2010) examined parental scaffolding when using a shape sorter with their 19-month-old infants during a play session. Half of the dyads were given a traditional, non-electronic shape sorter and half of the dyads were given an electronic shape sorter that had sound effects and lit up. They found significant differences in the type and level of parental scaffolding for
each type of shape sorter. Parents in the electronic group provided less verbal shape information and performed fewer shape actions (e.g., helping child rotate shape to fit correctly) than parents assigned to play with the non-electronic shape sorter. These findings suggest parents might assume electronic toys will enhance infant learning on their own. This reduction in appropriate scaffolding could, in turn reduce infant learning. The touch screen provides a novel analog for examining how technology influences infants’ understanding of cause and effect relationships (e.g., push a button to produce a sound effect) in addition to how parent scaffolding influences infant learning from electronic sources.

Touch screens are becoming more important in today’s society but this dissertation has shown it is difficult for infants to learn in this type of situation. As technology continues to advance for adults, it is also likely new technology produced for young children will continue to increase. Touch screen methodology provides an important avenue for future research to gain a better understanding of the factors involved in transfer of learning in this digital age. Ultimately, the context in which transfer of learning between 2D and 3D occurs is something that is often overlooked but is likely to be critical to the design and use of media as an effective teaching tool with infants.
References


