KNOWLEDGE ACQUISITION OF PRESCHOOLERS FROM TECHNOLOGICAL SOURCES

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This is to certify that I have examined this copy of the dissertation by

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THESIS ABSTRACT

This dissertation investigated the factors influencing preschoolers' knowledge acquisition from different technological sources, with the aim of understanding children's learning processes. In Chapter I, the factors that affect children's assessment of the possibility of events in stories, and their learning of a novel causal relationship from picture books were examined. Our findings showed that the platform on which the story was read (paper or touchscreen device) had no effect on children's (N = 187) possibility judgments or learning. On the other hand, when children believed that the causal relationship presented in the story can happen in the real world, they were more likely to learn that information. Children were also more likely to learn the target information from an animated electronic book than an electronic book without animations. Last, children's fantasy orientation influenced their assessment of the possibility of story events but not their learning from the story. These results indicate that preschoolers do not make a distinction between print and electronic books whereas they are more likely to learn the information they find realistic, and that animations in electronic books also affect this possibility. Chapter II discussed how Augmented Reality can contribute to children's learning in the light of research on cognitive development. To that end, research on children's learning from realistic and non-realistic contexts, and from screens were reviewed. Based on the review, this chapter suggests that Augmented Reality can support learning by directing children's attention to the educational content and encouraging children to reflect on it, and by reducing the dissimilarity between the contexts of encoding and retrieval of new information. Chapter III examined children's selectivity among different sources of information across different domains of knowledge. Results revealed that children (N = 80) judged social robots as better informants than cartoon characters but worse informants than adults. However, as children perceived social robots more animate than inanimate, they were more likely to judge robots as more knowledgeable than humans. Children further judged social robots as most knowledgeable about machines and least about psychology and biology, suggesting that children attribute certain expertise to technologial informants. In sum, this dissertation concludes that children can learn new information from technological sources but they are selective in their learning, and that children's selectivity is grounded on their understanding of reality. Children are prone to learning the information they can relate to the world they know and experience.

Keywords: preschool, learning, technology, reality-fantasy distinction

TEZ ÖZETİ

Bu doktora tezi okul öncesi dönemde çocukların farklı teknolojik kaynaklardan yeni bilgi edinmelerinde rol oynayan etmenleri incelemekte, bu şekilde çocukların öğrenme süreçlerine ışık tutmayı amaçlamaktadır. Bölüm I'de çocukların resimli kitaplarda gördükleri olayların gerçekleşme olasılığını değerlendirmelerini ve kitaplardan daha önce duymadıkları bir nedensel ilişkiyi öğrenmelerini etkileyen faktörler incelenmiştir. Çalışmanın bulguları, hikayenin okunduğu platformun (basılı kitap veya dokunmatik ekranlı cihazda okunan elektronik kitap) çocukların (N = 187) olasılık yargıları veya bilgi edinmeleri üstünde bir etkisi olmadığına işaret etmektedir. Buna karşılık, çocuklar hikayede sunulan nedensel ilişkinin gerçekleşebileceğine inandıklarında o bilgiyi öğrenme olasılıkları artmaktadır. Ayrıca çocukların animasyonlu bir elektronik kitaptan bilgi öğrenme olasılıkları animasyonsuz bir elektronik kitaba göre daha fazladır. Son olarak, çocukların hayal gücü yatkınlıkları hikayedeki olayların olasılığını değerlendirmelerini etkilemekte, ancak kitaptan bilgi öğrenmelerini etkilememektedir. Bu bulgular, çocukların basılı ve elektronik kitaplar arasında bir ayrım gözetmediğini, ancak gerçekçi buldukları bilgileri öğrenme olasılıklarının daha fazla olduğunu, ve elektronik kitaplardaki animasyonların da bu olasılığı arttırdığını göstermektedir. Bölüm II, artırılmış gerçeklik uygulamalarının okul öncesi dönemde çocukların öğrenme süreçlerine nasıl katkıda bulunabileceğini bilişsel gelişim araştırmaları ışığında tartışmaktadır. Bu amaçla, çocukların gerçekçi ve gerçek dışı bağlamlardan öğrenmelerine dair çalışmalar ile ekranlardan öğrenmelerini etkileyen etmenlere dair çalışmalar incelenmiş ve değerlendirilmiştir. Bu bölüm, bu çalışmalara dayanarak, artırılmış gerçeklik uygulamalarının çocukların dikkatini eğitsel içeriğe yönlendirip onları bu içerik üzerine düşünmeye teşvik ederek ve bilgi kodlama ile hatırlama bağlamları arasındaki farklılığı azaltarak öğrenme süreçlerini destekleyebileceğini öne sürmektedir. Bölüm III, çocukların farklı bilgi kaynakları arasında yaptıkları seçimi etkileyen etmenleri incelemektedir. Çocuklar (N = 80), sosyal robotları çizgi film karakterlerine göre daha fazla, ancak yetişkinlere kıyasla daha az bilgili görmektedir. Buna karşılık, çocuklar sosyal robotları daha canlı varlıklar olarak algıladıkça robotları insanlara göre daha bilgili bulmaktadır. Ayrıca çocuklar, sosyal robotların makineler hakkında bilgili, psikoloji ve biyoloji ile ilgili konularda ise bilgisiz olduğunu düşünmektedir. Sonuç olarak, bu tezde çocukların teknolojik kaynaklardan öğrenme süreçlerinde seçici davrandıkları ve bu seçiciliklerinin çocukların gerçeklik anlayışına dayalı olduğu sonuçlarına varılmıştır. Çocuklar deneyimledikleri dünya ile ilişkilendirebildikleri bilgileri öğrenmeye yatkınlardır.

Anahtar sözcükler: okul öncesi, öğrenme, teknoloji, hayal-gerçek ayrımı

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OVERVIEW

Children learn by experimenting with the world, interacting with and observing other people, and analyzing patterns of data that they obtain (Gopnik, 2012). They do not only collect data from their direct interactions and observations but also from the testimonies of others (Harris & Koenig, 2006). With technological advancements, children's sources of data are becoming diversified. There is now an influx of media platforms with which children may learn about the world, from mobile applications to social robots. Just like they do not unconditionally accept and learn everything they hear or see from other people, children are also selective in choosing when to learn and when not to learn from digital sources (Brosseau-Liard, 2017). This dissertation aims to understand the factors influencing children's learning from different digital sources, namely electronic books, Augmented Reality, and social robots.

When learning from other people, children show *selective trust* (Koenig & Harris, 2005), *epistemic vigilance* (Sperber et al., 2010) or *critical stance* (Mills, 2013). While these terms slightly differ from each other, they all imply that children are skeptical about a novel piece of information, and that they put some cognitive effort into distinguishing useful, accurate, reliable information from information that is not. To be able to do so, in learning and developing concepts about the world, children make use of a wide range of cues, such as the linguistic cues in the testimonies of others (Gelman, 2009). This is a constructive process: To build a coherent understanding of a concept, children rework what other people tell them about the world (Harris & Koenig, 2006). Is this also the case when the source of information is not a person but a digital device? Given that during concept construction children take the inherent characteristics of the informant into consideration (e.g., age, social status, expertise) in addition to evaluating the content that the person provides (Mills, 2013), digital devices offer the opportunity to examine if children's critical stance expands to non-human sources of information. Altogether, digital devices are a different kind than humans, yet they also differ among themselves as illustrated by the distinction between a touchscreen device (i.e., a machine) and a humanoid robot (i.e., an anthropomorphized machine). Studying children's selective learning from different non-human sources of information can provide a better insight regarding the scope of children's critical source evaluation. More specifically, it allows for understanding if children use similar heuristics in evaluating non-social sources as they use for social sources, hence if the mechanisms children employ for source evaluation are domain-general or not (Danovitch & Alzahabi, 2013).

Children's selective learning specifically in their preschool years has received the most attention from researchers since that is when most change in their selectivity seems to occur (Mills, 2013). Hence, this dissertation focuses on children between 3 to 6 years of age. This is also the age range when children are most exposed to digital media with implicit and explicit learning objectives, and preschoolers can learn the intended curriculum from those digital content (Fisch, Kirkorian, & Anderson, 2005). This highlights the importance of understanding the factors playing a role in young children's learning from technology, and designing their digital learning experiences accordingly. Therefore, in three chapters, this dissertation aims to contribute towards that purpose by answering the question of when preschoolers learn from technological sources.

One prevalent platform children learn from is books, which is the main subject of Chapter I. Children today read fictional stories not only in print but also on digital media such as electronic books (i.e, e-books). E-books are narratives presented on touchscreen devices, and unlike print books, they may include multimedia features such as sounds, and interactive features such as games (Kucirkova, 2019). They are commercially widely available, and are receiving attention not only from parents and teachers but also from researchers, especially in terms of their effects on children's story comprehension and word learning (Lauricella, Blackwell, & Wartella, 2017). Just like print books, e-books may include various new pieces of information children may learn about, one being novel causal relationships (e.g., rain causes rainbows to appear in the sky), which is the focus of Chapter I.

The contexts children are in may not always explicitly signal to them whether a new piece of information is applicable in the real world or not (e.g., rain causes rainbows but not unicorns to appear in the sky), as in the absence of an adult who can make clarifications. In such instances, children make use of other cues to decide if a piece of information in the story is real or not, and hence, if it can be applied to the real world (Hopkins & Weisberg, 2017). In Chapter I, we investigate the factors affecting children's possibility judgments regarding the events in stories (i.e., whether they can happen in the real world), and children's generalization of a novel causal relationship from those stories. To that end, we focus on the effects of the possibility structure of the story (realistic or fantastical), the medium on which the story is presented (print or electronic), representations of events (still illustrations or moving animations), and children's fantasy orientation (i.e., their engagement with fantasy-related thoughts, behaviors, and interests).

While we accumulate a vast body of work on e-books as developmental researchers, technological advancements continue transforming children's interactions with screen media. One such advancement is Augmented Reality (AR), which is the focus of Chapter II. Technology today allows for combining real and virtual worlds in different ways and amounts on a *virtuality continuum*, ranging from completely real to fully computer-generated environments with mixed reality in between (Milgram & Kishino, 1994). In contrast to Virtual Reality where the physical world is obstructed by the computer-generated environment, AR superimposes virtual information onto the immediate physical surrounding of the user (Milgram, Takemura, Utsumi & Kishino, 1995). In Chapter II, we focus on mobile AR applications where the virtual information is presented on a screen (as opposed to a head-mounted display or spatial displays where the information is projected onto a physical surface; Kesim & Ozarslan, 2012), as in e-books. For instance, when reading a print picture book, children may see the characters moving and talking on the screen in 3D by allowing the book and the mobile device to interact through the AR application.

AR had begun to be used for educational purposes, including targeting young children (Akçayır & Akçayır, 2017) yet the cognitive mechanisms underlying children's learning with AR had received little attention. For instance, it was argued that children's motor, spatial, attention, and memory abilities must be taken into consideration when designing AR applications targeting children between 6 and 9 years of age (Radu & MacIntyre, 2012). However, AR taps into other cognitive processes of children as well, especially when we consider younger children. Particularly, as the picture book example above illustrates, AR blurs the line between the real and virtual worlds by presenting virtual information on the real environment around children. As also addressed in Chapter I, associating a novel piece of information with the real world has consequences for young children's learning. Therefore, in Chapter II, we aim to explain how and why AR may contribute to preschoolers' knowledge acquisition. We ground our arguments on the research on children's reality-fantasy distinctions and their learning from screen media.

The first two chapters of this dissertation focuses on children's learning within the types of one medium (print and electronic books), and from a single medium (AR). Nonetheless, as mentioned earlier, the number of sources children may learn from is increasing with the technological advancements. To understand if and when children show selectivity across agents, Chapter III compares children's perception of different informants as sources of information across different domains of knowledge. To that end, we pit social robots against human adults and cartoon characters.

Social robots are robots that (semi-)autonomously interact and communicate with humans by following the norms, values, and standards common to humans (Bartneck &

Forlizzi, 2004). Due to their social and physical abilities as well as their physical embodiment, social robots such as NAO and Robovie draw interest for their potential in educational settings (Belpaeme et al., 2016; Belpaeme, Kennedy, Ramachandran, Scassellati, & Tanaka, 2018). For instance, social robots can perform actions and gestures, and provide verbal and nonverbal feedback to contribute to children's learning (Kanero et al., 2018). Researchers test the efficacy of social robots in teaching children a wide range of subjects including prime numbers (e.g., Kennedy, Baxter, Senft, & Belpaeme, 2015), simple machines (e.g., Hashimoto, Kobayashi, Polishuk, & Verner, 2013), and a foreign language (Vogt et al., 2019), or in improving social skills of children with Autism Spectrum Disorder (Robins, Dautenhahn, Te Boekhorst, & Billard, 2005). Children are open to learn from robots (Breazeal et al., 2016), yet they also have complex preconceptions about what robots really are (i.e., if they have cognitive, social, moral abilities; Kahn et al., 2012). In Chapter III, we investigate how children's conceptualizations of robots influence their epistemic decisions across different domains of knowledge and in comparison to other informants.

In sum, the three chapters in this dissertation shed light onto the factors influencing children's learning from different technological sources. We aim to understand if children show a critical stance towards non-human sources of information. To that end, Chapter I presents the manuscript of the journal article to be submitted, Chapter II presents the manuscript published in *The International Journal of Child-Computer Interaction*, and Chapter III presents the manuscript submitted to *Cognitive Development*. The works published and presented during the PhD are listed below.

List of Publications

Oranç, C., Baykal, G. E., Kanero, J., Küntay, A. C., & Göksun, T. (Accepted). A look into the future: How digital tools may advance language development. In K. Rohlfing & C. Müller-Brauers (Eds.), *Early literacy and (digital) media: changes in social interaction and literacy development*. Abingdon, UK: Routledge.

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Verhagen, J., Wallbridge, C. D., Willemsen, B., de Wit, J., Geçkin, V., Hoffmann, L., Kopp, S., Krahmer, E., Mamus, E., Montanier, J. M., **Oranç, C.**, Pandey, A. K. (2018). Guidelines for designing social robots as second language tutors. *International Journal of Social Robotics, 10,* 325–341.

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List of Presentations

* Asterisk denotes the presenter

Kanero, J.*, **Oranç, C.**, Koşkulu, S., Göksun, T., & Küntay, A. C. (2019, July). *When do iconic gestures facilitate word learning? The case of L2 lessons for preschoolers led by a robot or human tutor*. The 41st Annual Meeting of the Cognitive Science Society, Montreal, Canada.

Oranç, C.*, İleri, Ç. İ., & Küntay, A. C. (2019, March). *Preschoolers' causal learning from print and electronic books*. Society for Research in Child Development Biennial Meeting, Baltimore, MD, USA.

Oranç, C.*, İleri, Ç. İ., Küntay, A. C. (2018, November). *Okul öncesi dönemde çocukların basılı ve elektronik kitaplarda gerçeklik algısı (Preschoolers' reality judgments in paper and electronic books),* 20th National Psychology Congress, TED University, Ankara, Turkey.

Koşkulu, S., **Oranç, C.***, Kanero, J., Göksun, T., & Küntay, A. C. (2018, November). *Robotların jestler ve geri bildirim ile okul öncesi dönemde İngilizce egitimine katkıları (Robots' contribution to early English education by gestures and feedback)*, 20th National Psychology Congress, TED University, Ankara, Turkey.

Demir-Lira, Ö. E.*, Kanero, J., **Oranç, C.**, Koşkulu, S., Franko, I., Uluşahin, O., Adigüzel, Z., & Göksun, T. (2018, November). *Using gestures in L2 vocabulary teaching: Human or robot tutors?,* The 43rd Annual Boston University Conference on Language Development, Boston, MA, USA.

Kanero, J.*, Franko, I., **Oranç, C.**, Uluşahin, O., Koşkulu, S., Adigüzel, Z., Küntay, A. C., & Göksun, T. (2018, September). *Who can benefit from robots? Effects of individual* *differences in robot-assisted language learning*, 8th Joint IEEE International Conference on Development and Learning and on Epigenetic Robotics, Tokyo, Japan.

Kanero, J.*, Demir-Lira, Ö. E., Koşkulu, S., **Oranç, C.**, Franko, I., Göksun, T., & Küntay, A. C. (2018, August). *How do robot gestures help second language learning?*, EARLI Conference on SIG 5 Learning and Development in Early Childhood, Berlin, Germany.

Demir-Lira, Ö. E., **Oranç, C.**, Kanero, J., Koşkulu, S.*, Franko, I., Adigüzel, Z., Göksun, T., & Küntay, A. C. (2018, April). *Effects of the gestures of social robots on children's second language learning*, Turkey Robotics Conference, Istanbul, Turkey.

Kanero, J.*, de Haas, M., Mamus, E., **Oranç, C.**, van den Berghe, R., Verhagen, J., Oudgenoeg-Paz, O., Bergmann, K., Schodde, T., Küntay, A. C., Göksun, T., Vogt, P., (2017, October). *Observing human tutoring to develop robot-based language lessons*. Symposium on Multimodal Communication 2017, Bielefeld, Germany.

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Oranç, C.* & Küntay, A. C. (2017, April). *Learning of new information from books is associated with perception of event reality and fantasy orientation in preschoolers*, Society for Research in Child Development Biennial Meeting, Austin, TX, USA.

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Oranç, C.* & Küntay, A. C. (2017, January). *Not their age but children's fantastical beliefs affect their reality judgments,* 6th Budapest Central European University Conference on Cognitive Development, Budapest, Hungary.

Oranç, C.* & Küntay, A. C. (2016, October*). Dragons don't exist in e-books: Children's understanding of impossibility across different media*, Society for Research in Child Development Special Topic Meeting: Technology and Media in Children's Development, Irvine, CA, USA.

CHAPTER I

LEARNING FROM FICTION ON PRINT AND ELECTRONIC BOOKS: SAME OR DIFFERENT?

Abstract

Fictional stories include a vast range of new information children can learn about the world. In this study, we investigated several factors influencing children's learning of a novel causal relationship from fictional picture books. Preschoolers (*N* = 187) read one of the six picture books changing in terms of the possibility of events in the story (realistic or fantastical), medium (print or electronic book), and the portrayal of events in electronic books (animated or non-animated), which were otherwise identical. The same target causal event was embedded in all six books. Children's categorization of the story events based on their possibility to occur, their generalization of the target event to the real world, and their fantasy orientation were measured. Results revealed that children's generalization of the target causal relationship was not dependent on the possibility of events but their own categorization of that relationship as possible to happen in the real world. Furthermore, children generalized the target information equally well from print and electronic books, yet they were more likely to generalize when the story events were animated in an e-book than when they were not. Last, children's fantasy orientation influenced their possibility categorizations of story events but not their generalization of the target causal event. This study sheds light onto important book-related and child-related factors influencing preschoolers' learning of new causal information from fictional stories.

Keywords: fiction, electronic books, learning, reality-fantasy distinction, fantasy orientation

Introduction

Children are often presented with new information in fictional contexts as in cartoons and picture books. To decide whether a word *Dora the Explorer* teaches is a real word in an actual language or to learn a lesson from a *Dr. Seuss* book, children need to determine whether the new piece of information only applies in that fictional world or it can be generalized to the real world (Hopkins & Weisberg, 2017). This *reader's dilemma* (i.e., the need to decide whether the information presented in a fictional context is applicable in the real world) holds true for adults (Gerrig & Prentice, 1991) and children alike (Hopkins & Weisberg, 2017). In our study, we investigated the factors which may influence children's possibility judgments of story events and their learning: the possibility structure of the story, the medium on which the story is presented, and children's fantasy orientation (i.e., their general engagement with fantasy-related interests and thoughts).

One of the many types of information children may encounter in fiction is causal relationships. Children learn about causal relationships of our world by observing patterns of data, and they take the causal structure of an environment into consideration when making causal inferences (Sobel & Legare, 2014; Sobel, Tenenbaum, & Gopnik, 2004). Fiction provides opportunities for learning new causal information. For instance, in the famous Aesop fable, a thirsty crow drops pebbles into a half-full pitcher to raise the water level so that he can drink it. Although children's books are loaded with such causal relations, they do not always have the same causal structure of our world, as is the case with fantastical stories where impossible events occur. The unusual causal structure of a fantastical world may influence children's decisions of generalizing a piece of causal information from that story to the real world (Walker, Gopnik, & Ganea, 2015). Furthermore, with technological advancements, children are exposed to fictional content with different causal structures on different mediums than print books such as electronic books. The ways in which these factors affect how children relate stories to reality and learn from them are discussed below.

Story Theme and the Possibility of Events

To solve readers' dilemma, one cue children use is the possibility structure of the fictional world. Stories may take place in a realistic setting that accurately represents the real world we know or in a fantastical setting where the real-world laws are violated, as is the case with impossible events (e.g., dogs flying) and nonexistent creatures (e.g., fairies). Over the preschool years, children begin to use the context in which a new piece of information is presented to decide if that information is real or not. They think events in a realistic story can happen in real life but not events in a fantastical story (Woolley & Cox, 2007). Similarly, they judge unfamiliar entities as real when they hear about them in relation to scientific entities but not when they hear about them in relation to fantastical entities (Woolley & Van Reet, 2006).

Understanding the reality status of the context translates into children's learning. In other words, the possibility of events in stories affects children's learning from them. Many studies show that children are more likely to learn a piece of information when it is presented in a realistic setting compared to a fantastical setting. One reason underlying these findings may be that it is easier to transfer a new piece of information from one context to another as the learning (e.g., book) and the application (e.g., real world) settings are more similar to each other (Barnett & Ceci, 2012). In other words, children may be able to associate a new piece of information with their own world knowledge when it is presented in a realistic, thus familiar, setting, which in turn makes it more sensible for them to add that information to their knowledge base.

Many studies support this argument. For instance, when preschoolers watch a pretend puppet scenario with plausible events (e.g., a loris eating an apple), they are more likely to extend that information to real lorises compared to when they watch a scenario with implausible events (e.g., a loris driving a truck; Sutherland & Friedman, 2013). This is the case for children's books as well. Preschoolers are more likely to apply a problem solution themselves to a similar problem when they hear about that solution in a story about real characters than fantasy characters (Richert, Shawber, Hoffman, & Taylor, 2009; Richert & Smith, 2011). Anthropomorphization has a similar effect to fantasy. Preschoolers learn about animals better when the book has realistic instead of anthropomorphized illustrations and language about animals (Ganea, Canfield, Simons-Ghafari, & Chou, 2014), and they learn prosocial behaviors such as sharing better when they hear a story about the importance of sharing in a book with human characters compared to one with anthropomorphized animals (Larsen, Lee, & Ganea, 2017). Finally, as children get older from 3 to 5 years of age, they are less likely to generalize a novel causal information (e.g., "popple flowers make people get hiccups") when they read it in a fantastical book than in a book with realistic events (Walker et al., 2015).

Preschoolers not only develop a sensitivity towards the possibility structure of stories with age, which informs their learning, but they are also more likely to learn a piece of information when they think it can happen in reality. In the aforementioned study (Walker et al., 2015), researchers observed a significant relationship between children's generalization of the target information and their categorization of that information as real. This applies to other media as well. Preschoolers are more likely to acquire new knowledge from television when they think that the information presented on the screen is real (Bonus & Mares, 2019; Mares & Sivakumar, 2014). Therefore, it is not only the realism of the story influencing children's learning but also their perception of the target information as possible.

Given that books, television shows, and movies targeting children frequently have supernatural elements (Goldstein & Alperson, 2019), it may sound puzzling that children learn better from realistic than fantastical stories. However, it was argued that fantastical themes may also contribute to children's learning by attracting their attention via unconventional scenes and guiding them to reflect on the educational content, hence leading them to put more cognitive processing to push the limits of their prior knowledge (Weisberg, Hirsh-Pasek, Golinkoff, & McCandliss, 2014). For instance, in the case of causal learning, it was suggested that children are more likely to seek for explanations in the face of an inconsistency with their prior knowledge, which in turn benefits their causal reasoning and learning (Sobel & Legare, 2014). Studies showing that infants and preschoolers learn about the properties and names of objects better when those objects violate their expectations support this argument (Stahl & Feigenson, 2015; 2017). So do studies about fictional contexts. Children who heard a fantastical story and played with related toys for 2 weeks were better in explaining the meaning of the target words from the story than children who were exposed to a realistic story and toys, although both groups were equally good in comprehending the words (Weisberg et al., 2015). Importantly, both books included anthropomorphic animals but only the fantastical book had events that defied reality, indicating that the way in which fantasy elements are embedded in the story may affect children's learning.

Indeed, Hopkins and Weisberg (2017) suggest that the discrepancy between findings regarding realistic and fantastical stories may be stemming from the use of fantasy in different types and amounts across studies. Supporting this argument, Richert and Schlesinger (2017) found that preschoolers were more likely to apply a problem solution themselves when they watched a similar situation in a video either with low levels of fantasy (e.g., unusual hair and skin colors) or with fantasy elements directly related to the solution (e.g., anthropomorphized animals performing the solution) compared to a video with fantasy elements unrelated to the target information (e.g., anthropomorphized animals dancing). The type of information targeted for learning may also explain the differences in the effects of fantasy in books. It was argued that fantasy elements may be most detrimental to learn biological information and problem-solving strategies from books, and less detrimental for physical concepts where children object to reality violations less often (Strouse, Nyhout, & Ganea, 2018).

In short, children can learn from fiction, yet they need to solve the reader's dilemma by discriminating what is real from not, and by making an informed decision on whether it can be applied in the real world (Hopkins & Weisberg, 2017). In this study, we investigate when and how preschoolers put these steps into practice.

Book Format and Features

Whether realistic or fantastical, children are exposed to fictional content on different mediums, including print and electronic books (i.e., e-books, which are mostly presented on touchscreen devices such as tablets). Research on children's learning from e-books mainly focuses on language development such as word acquisition, and they offer mixed results about the efficiency of e-books as educational tools, possibly due to the methodological differences as in control conditions and the features of book stimuli (Lauricella, Blackwell, & Wartella, 2017).

As Hopkins and Weisberg (2017) indicate, studies comparing print and e-books in a controlled manner (i.e., in terms of content and design) are scarce, yet existing studies show that children can learn both from print and e-books even though the latter has some constraints. In one such study (Strouse & Ganea, 2017), toddlers between 17 to 30 months were all able to recognize the name of an object after hearing it in a print or electronic book. However, only those who were older than 24 months could generalize the words they learned from an e-book to other examplars of the object and the real world, even though younger children were able to do so after listening to the print book. In another study with older children (Raynaudo & Peralta, 2019), 4-year-olds learned about the concept of camouflage equally well with print and e-books, as they were all able to correctly identify the animal that would not get eaten by a predator after reading a story about camouflage. However, children who were in the print book condition were better in justifying their responses in terms of camouflage compared to their peers in the e-book condition. One characteristic of these studies is that they are about factual and not fictional books. We do not know yet if and how children's learning, or causal knowledge acquisition more specifically, from fictional e-books is different than print books.

In addition to the medium of presentation, medium-specific features may also influence children's learning. An e-book may be the replica of a print book with the sole difference of being presented on a screen, but can also have many features that are not possible with print books such as animations, sound effects, and interactive games. One meta-analysis showed that compared to print books, multimedia features of e-books (e.g., animations, sound effects, background music) positively affect children's expressive vocabulary knowledge and story comprehension whereas interactive features (e.g., games, questions, hotspots) may have adverse effects (Takacs, Swart, & Bus, 2015). Although there are studies showing that children's story comprehension and word learning are equally good from print and e-books (e.g., Korat, 2010; Richter & Courage, 2017; Smeets & Bus, 2015; Verhallen & Bus, 2010; Zipke, 2017), studies often fail to carefully isolate the effect of one multimedia or interactive feature from others as they often combine different features. This makes it difficult to make inferences about the actual impact of different features, either individually or additively.

Among these features, animations in fictional e-books are especially worth investigating. It was suggested that dynamic representations of events in videos facilitate children's story comprehension more than still images by enhancing children's encoding of the story elements (Sharp et al., 1995). Relatedly, animations in e-books were found to foster deeper learning than still illustrations in the case of vocabulary learning. While children understood word meanings equally well when the words were dynamically or statically represented in an e-book, children were better in explaining the word meanings when the illustrations of words were animated (Korat, Levin, Atishkin, & Turgeman, 2014; Verhallen & Bus, 2010). It was argued that dynamic depictions contribute to word learning by drawing children's attention to the parts of the target concept one by one instead of introducing all information at once, which in turn creates a stronger memory for that word (Verhallen & Bus, 2010). In our study, we investigate if the same rationale applies to children's learning of causal relationships from e-books.

Not only children's learning but also their possibility judgments of stories may differ across different representations of events. To our knowledge, there are not any studies comparing preschoolers' possibility judgments of events across book formats or animated and non-animated e-books. On one hand, preschoolers were suggested to be equally skeptical about the reality status of events across different media including television (where events are dynamically depicted) and story books (with still images of events; Woolley & Ghossainy, 2013). On the other hand, Lillard and Taggart (2019) speculated that while unanimated depiction of fantastical events may benefit children's learning by drawing their attention, animated portrayals of fantastical events may lead to confusions and interfere with their learning. To test this argument, as Li, Boguszewski, and Lillard (2015) suggested, research is needed to compare children's possibility judgments across various media with different portrayals of events. To that end, in this study, we not only compare children's possibility judgements between print and electronic books but also between animated and non-animated e-books.

Fantasy Orientation

Fantasy orientation (FO) is an individual's engagement with fantasy-related interests and thoughts that might cover a wide range from having imaginary companions to engaging in pretend play or believing in fantastical entities such as fairies (Pierucci, O'Brien, McInnis, Gilpin, & Barber, 2014). It was suggested that children's FO may help explaining their reality judgments and learning from books (Walker et al., 2015) as well as digital media (Mares & Sivakumar, 2014), and that individual differences in FO may even explain children's reality judgments better than their age (Woolley & Cornelius, 2013).

There are mixed findings regarding the effect of FO on children's reality-fantasy distinctions and their learning from fictional contexts (Weisberg, 2013). On one hand, 3- to 5-year-old children with higher FO were more accurate in their categorization of different entities (e.g., a clown, a monster) as real or pretend (Sharon & Woolley, 2004). Furthermore, children who had higher levels of FO were less likely to transfer problem solutions to the real world from a fantastical book whereas FO did not affect their transfer from a realistic book (Richert & Smith, 2011). These findings suggest that having more experience with fantasy worlds may help children to make more correct reality judgments, which in turn influence their learning. On the other hand, children of the same age with higher FO were more likely to develop beliefs for a novel fantastical entity, indicating their credulity (Woolley, Boerger, & Markman, 2004). However, in a follow-up study, it was not the overall FO but the number of fantastical entities children believe in predicting their belief in a newly introduced entity (Boerger, Tullos, & Woolley, 2009). Researchers suggested that the discrepancy between the two studies may be resulting from the larger sample size of the latter.

Indeed, even though FO had been treated as a composite measure in most studies above, FO is an umbrella term encompassing distinct components. Pierucci and colleagues (2014) suggest that it has four separate constructs: cognitions (holding fantastical thoughts), entities (believing in fantastical entities), toys and games (having favorite toys and games that have fantastical themes), and pretense (engaging in pretense activities). Hence, we aim to explore the specific components of FO influencing children's possibility judgments and learning across different fictional contexts and book formats.

The Present Study

In the light of research reviewed above, we investigated if and how does the theme of the story, the medium on which the story is presented, and preschoolers' FO affect (a) their possibility judgments of the events in the story, and (b) their generalization of a causal event from the story to the real world. We further examined the effect of animations in e-books on these two outcomes.

For (a) we predicted that children will judge more of the realistic story events as possible than the fantastical story events, irrespective of the book format. For (b) we predicted that (i) children will generalize causal events from realistic stories compared to fantastical stories, (ii) they will generalize if they think the target event can happen in the real world, (iii) book format will not influence these effects, and (iv) children will generalize from the animated e-book compared to non-animated e-book. The effects of FO were planned to be exploratory, since to our knowledge, ours is the first study to break FO down into separate constructs when investigating children's possibility judgments and their learning from fiction.

As Hopkins and Weisberg (2017) indicated, the field currently lacks a systematic comparison of different media types in terms of children's learning from fiction. We aim to expand previous studies investigating children's learning from fiction on paper (e.g., Walker et al., 2015) to screens. Furthermore, many studies incorporate multiple multimedia and interactive features into their e-books, which distracts us from the isolated effect of both the media format and the specific features. This study helps filling that gap by providing a careful comparison between print and e-books. By investigating story possibility, book format and features, we aim to provide insight into the factors affecting children's reality-fantasy distinctions and learning of causal relations from fiction.

Method

Participants

Participants were 187 children between the ages of 36 and 72 months (M = 53.82, SD = 9.04; 90 girls). Children were recruited through local preschools in Istanbul, Turkey. They were compensated for their time with a picture book.

Materials and Procedure

The study had a 2x2x2 between-subjects design with story theme (realistic, fantastical) and book format (print, electronic) as factors, and animation (with, without) as an additional between-subjects factor within the electronic book condition. Thus, there were print, animated e-book, and non-animated e-book versions of both realistic and fantastical stories, totaling to six independent experimental conditions: Realistic print book, realistic animated e-book, realistic non-animated e-book, fantastical print book, fantastical animated e-book, and fantastical non-animated e-book.

Picture book reading. Two stories were written and illustrated for experimental purposes, telling the story of a boy or a girl (changing depending on the sex of the participant) preparing to go to school in the morning. Both stories included the same sequence of five events in the same order but the possibility of events, hence the theme, differed across books: Realistic and fantastical. The realistic story included ordinary daily events (e.g., finding clothes in the wardrobe) whereas the fantastical story had elements violating our expectations about the world (e.g., finding a fairy in the wardrobe). The same novel causal event was embedded in both stories, where the protagonist sneezes as a result of drinking a fictitious juice. The story made it clear that the reason why protagonist sneezed was because he or she drank the “rubar” juice. The sample illustrations from the realistic and fantastical stories as well as the illustration of the causal event—which was identical in all books—can be seen in Figure 1.1 (All illustrations are presented in Appendix A). All books included the same number of words, pages, and illustrations.

(a) (b)

(c)

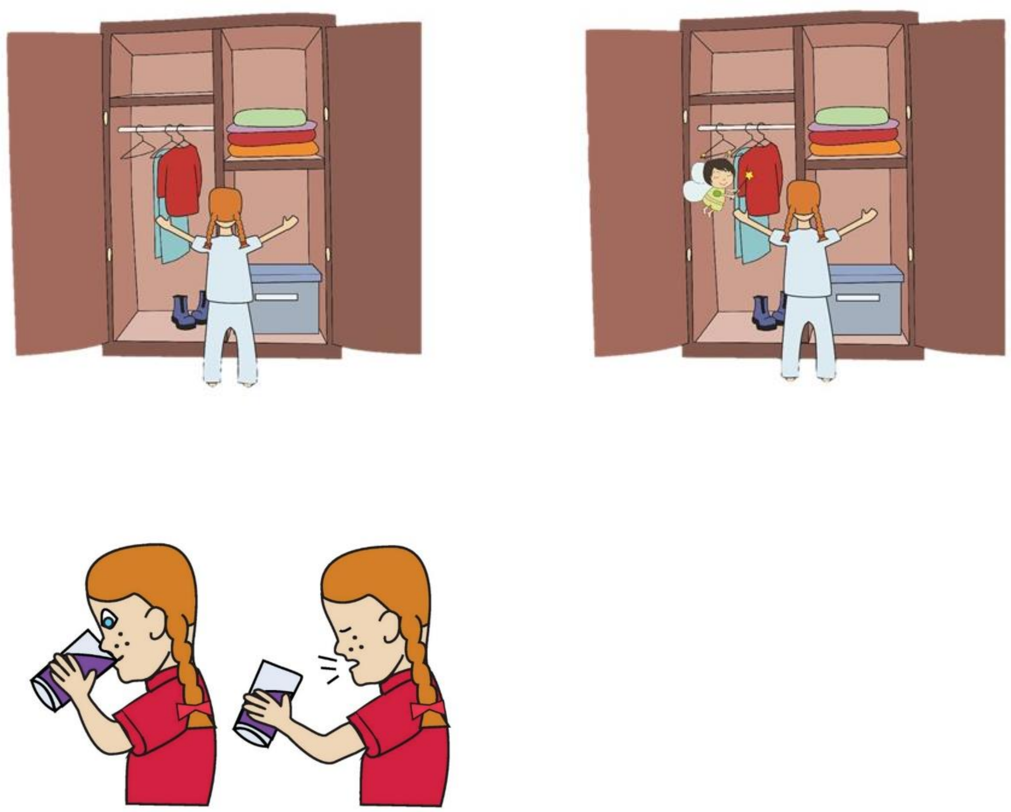

Figure 1.1. The sample illustrations for (a) realistic and (b) fantastical depictions of the same scene (i.e., opening the wardrobe), and (c) the target causal event.

The experimenter read children one of the two stories (i.e., realistic or fantastical) either on paper or on a touchscreen tablet. Among children who were read the e-book, half saw moving animations for the five events and the target event (i.e., animated e-book), whereas for the other half, the book was the exact digital copy of the print version, with no animations (i.e., non-animated e-book). Hence, the only difference between the print and the non-animated e-book was the medium on which the story was presented. The only difference between the non-animated and animated e-books was that in the latter, the illustrations were moving. E-books did not include any multimedia or interactive effects such as sound effects or background music, except for the moving illustrations in the animated e-book condition.

The experimenter met children at preschools, and read one of the six books one-on-one in a quiet room. She did not engage about the story with the child. If the child initiated such engagement, the experimenter encouraged the child to stay focused on the reading activity, and told the child that they can talk about the story when they are done with the study. Once the reading was complete, each child went through the following steps.

Memory interview. Children were asked the question “What happened in this story?” to measure their free recall of the story. The experimenter waited for the child to respond and if the child did not provide an answer, the experimenter repeated the question and encouraged the child to remember.

Card sorting task. This task was devised to measure the number of story events children judge to be able to happen in the real world, hence their possibility judgments of the key story elements. For each of the five events and the one novel causal event in the book, the experimenter showed the respective illustration from the book on a card, verbally described the event, and asked if that can happen in the real world. Children were asked to put the illustration card either into the “real” box where things could happen in the real world or the “fantasy” box where things could not happen in the real world. Four practice trials were administered for children to get familiar with the procedure where they were asked to sort cards of events unrelated to the story in this study. Two events were realistic (e.g., a woman talking on the phone) and two were fantastical (e.g., a child eating a cloud). The experimenter provided feedback when children correctly and incorrectly placed the cards during practice but not during the actual task.

Generalization task. This task was used to measure children's learning of the novel causal information that was embedded in the fictional context. Children were shown a photograph of a cup of juice in the same color as the fictitious juice in the story. The experimenter briefly told about a lunch they had with a friend and that they cannot remember all the details. Children were asked whether the friend who drank the juice in the photograph sneezed or not. As a control question, children were also shown a juice of a different color, orange, and were asked the same question. This was to ensure that children generalized the causal event only to the juice from the story and no other.

Fantasy orientation interview. Children were asked 9 questions borrowed and translated from Pierucci and colleagues (2014) to measure the four fantasy orientation constructs: cognitions (holding fantastical thoughts), entities (believing in fantastical entities), toys and games (having favorite toys and games that have fantastical themes) and pretense (engaging in pretense activities). All questions are presented in Appendix B.

Data Coding

Memory interview. The free recall question ("What happened in this story?") was coded based on the main elements of the story (0 = Not mentioned, 1 = Mentioned). The two breakfast elements (i.e., content of the breakfast and the characteristics of the kitchen) were merged (i.e., mentioning only one was sufficient to receive 1 point), and the target causal event was analyzed separately. Hence, a child who mentioned all 4 elements received a point of 4 and a child who did not mention any received a point of 0. A child who mentioned the target causal event incident received an extra 1 point.

Card sorting task. The number of cards children put in the "real" box served as the dependent variable for their possibility judgments of the story.

Generalization task. Children's verbal responses were recorded as a dichotomous variable (0 = Did not sneeze, 1 = Did sneeze).

Fantasy orientation interview. Answers to all questions were coded as fantasy-related (scored as 1) or reality-related (scored as 0). Answers that were not fantasy-related but had elements of pretense and imagination (e.g., playing house) were coded as 0.5, similar to Sharon and Woolley's (2004), and Boerger and colleagues' (2009) studies. For the questions with open-ended answers (i.e., "What do you think about before going to bed?", "What is your favorite toy?", "What is your favorite game?"), one independent rater and the first author coded children's answers. The Cronbach's α for these questions were 0.94, 0.93, and 0.86 in the respective order. The two coders discussed about their disagreements and finalized the coding together.

Results

Descriptives

Children's age did not differ across the six conditions, $F(5, 181) = 1.47$, $p = .202$, nor the distribution of their gender, χ^2 $(5, N = 187) = 5.215$, $p = .39$.

25.7% of children ($n = 48$) did not have a response for at least one of the nine FO questions (i.e., not answering, incomprehensible or irrelevant verbal responses). Given that we aimed to calculate children's score for each of the four FO construct (i.e., Cognitions, Toys and Games, Pretense, Entities), this posed the problem of losing those children as missing data for a given construct, even if they answered one of the questions. To avoid this, for each child, we calculated a proportion score for each FO construct by dividing children's FO score by the number of questions they responded for that construct (out of 3 for Entities and out of 2 for Cognitions, Toys and Games, Pretense). Thus, all children had a score between 0 and 1 for each of the four constructs, higher scores indicating higher FO. If they did not have an answer for any of the questions within a construct (e.g., no response for either of the two Pretense questions), they were treated as missing data for that specific construct (e.g., Pretense). The mean proportion of FO scores are presented in Table 1.1.

Table 1.1.

Children's mean proportion scores for four FO constructs (N = 187)

Construct	*n*	*M*	*SD*
Cognitions	178	0.242	0.333
Toys and Games	178	0.214	0.28
Pretense	171	0.559	0.371
Entities	186	0.163	0.32

Note. The column n indicates the number of children who responded at least one of the questions in a given construct, hence the number of children for whom a proportion score could be calculated.

There was not a significant correlation between any of the FO constructs (p values > .05), except for the one between Pretense and Cognitions, $\tau b = 0.146$, $p = .038$. Hence, we did not create a composite score of FO. Children's age was significantly and negatively correlated with Entities, $\tau b = -0.248$, $p < .001$, but not with the rest of the FO constructs, p values > .05.

Story Recall

In the analyses below, 2 children who had missing data for the free recall question were excluded. Mean number of events children recalled across the six conditions can be seen in Figure 1.2.

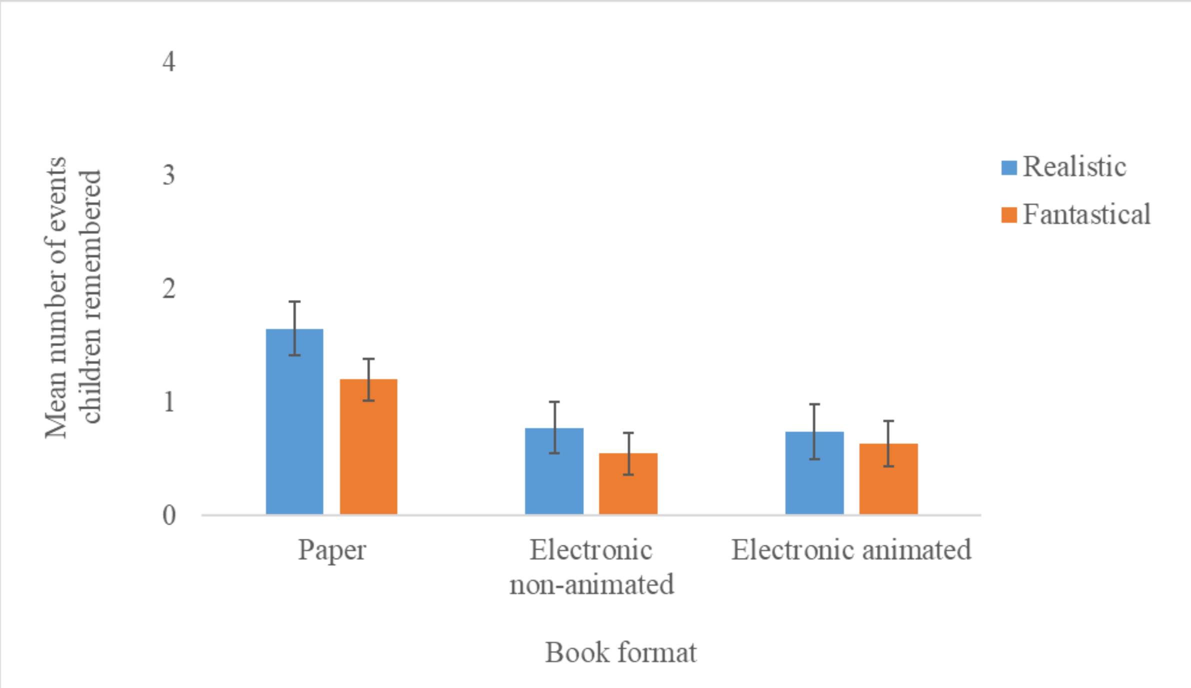

Figure 1.2. Mean number of events children reported for the free recall question across conditions

To understand the factors influencing children's story recall, we ran two analyses. First, we compared print and electronic book conditions by excluding children in the animated e-book condition (*n* = 46) to carefully match the book formats, resulting in 140 children as our final sample. A Poisson loglinear model predicting the number of events revealed a significant model, χ^2 (3, *N* = 140) = 33.539, *p* < .001, with the significant predictors theme, χ^2 (1, *N* = 140) = 4.614, *p* = .032; format, χ^2 (1, *N* = 140) = 14.333, *p* < .001; and age, χ^2 (1, *N* = 140) = 12.881, *p* < .001. Children were less likely to recall events when the story was read on an electronic book compared to paper, *B* = -0.722, *SE* = 0.205, *p* < .001, *OR* = 0.476, 95% CI [0.319 – 0.715], and from a fantastical story compared to a realistic story, *B* = -0.336, *SE* = 0.157, *p* = .033, *OR* = 0.715, 95% CI [0.524 – 0.971]. As children got older, they were more likely to recall more events, *B* = 0.031, *SE* = 0.008, *p* < .001, *OR* = 1.032, 95% CI [1.014 – 1.05].

A second model to predict the remembered events was run only with electronic book participants (n = 89) with the predictors Theme, Animation, and Age, and was found to be significant, χ^2 (3, N = 89) = 8.224, p = .042. While both Theme, χ^2 (1, N = 89) = 0.484, p = .487, and Animation were non-significant predictors, χ^2 (1, N = 89) = .428, p = 0.513, Age was significant, χ^2 (1, N = 89) = 7.3, p = .007. Again, older children were more likely to recall more events, B = 0.041, SE = 0.015, p = .008, OR = 1.042, 95% CI [1.011 – 1.074].

The percentages of children who recalled the target causal event (i.e., "drinking rubar juice causes one to sneeze") ranged from 9.1% to 17.4% across the six conditions. Fisher's exact test revealed that there was no relationship between condition and recalling the target event, p = .932.

Possibility Judgments

In the analyses below, 20 children who had missing data for any of the FO constructs and 2 children who had missing data for the story recall question were excluded.

How do book format and story theme affect children's possibility judgments of story events?

For this analysis, we excluded children in the animated e-book condition (n = 46) to carefully match the print and e-book conditions, which made our final sample of 121 children.

We originally built a Poisson loglinear model to predict the number of cards children put in the "real" box with the following factors: Children's age (in months), their free recall scores (0-4), their four FO construct proportion scores (Cognitions, Toys and Games, Pretense, Entities), Format (print, electronic), Theme (realistic, fantastical), Format x Theme interaction, all the 2-way interactions between Format, Theme, and the FO constructs. The model reached significance, χ^2 (26, N = 121) = 206.88, p < .001, yet to achieve parsimony and better model fit, we ran another model by excluding the non-significant interaction terms with FO.

The final model presented in Table 1.2. was significant, χ^2 (12, *N* = 121) = 202.957, *p* < .001. The effect of Format was not significant, χ^2 (1, *N* = 121) = 0.339, *p* = .56, nor the interaction between Theme and Format, χ^2 (1, *N* = 121) = 0.87, *p* = .351. Thus, the number of cards children put in the “real” box was not influenced by whether they saw the story on paper or on tablet. The effect of Theme was not significant, χ^2 (1, *N* = 121) = 3.179, *p* = .075. However, Theme interacted both with children’s Entity scores, χ^2 (1, *N* = 121) = 10.901, *p* = .001 and their age, χ^2 (1, *N* = 121) = 10.591, *p* < .001. The interaction between Theme and children’s Pretense scores was significant in the full model, yet it lost its effect in the reduced model, χ^2 (1, *N* = 121) = 3.584, *p* = .058.

As can be seen in Table 1.2, the more fantastical entities children believed in, the more likely they were to put cards in the “real” box for the fantastical story. Furthermore, as children got older, they were less likely to put the fantastical event cards in the “real “box. In both cases, their categorization of events was not influenced by their FO when they read the realistic story. Hence, children who believed in more fantastical entities and those who were younger were more prone to miscategorize the fantastical events.

Table 1.2

Parameter estimates for the Poisson model predicting the number of cards put in the "real" box across book formats and story themes (N = 121)

	B	*SE*	*OR*	95% CI
Intercept	1.447 **	0.389	4.25	[1.968 – 9.046]
Age	0.002	0.007	1.002	[0.988 – 1.016]
Free recall	-0.015	0.042	0.985	[0.907 – 1.069]
Theme = Fantastical (vs. Realistic)	1.711	1.067	5.532	[0.681 – 44.998]
Format = Electronic (vs. Print)	-0.054	0.133	0.947	[0.728 – 1.227]
Theme x Format	0.287	0.306	1.332	[0.726 – 2.416]
Theme x Age	-0.065 *	0.02	0.938	[0.9 – 0.975]
Cognitions	0.141	0.177	1.152	[0.809 – 1.622]
Toys and Games	0.086	0.172	1.09	[0.774 – 1.517]
Pretense	0.028	0.173	1.028	[0.733 – 1.445]
Entities	0.004	0.168	1.004	[0.715 – 1.384]
Theme x Entities	1.38 *	0.4	3.974	[1.782 – 8.583]
Theme x Pretense	-0.74	0.39	0.477	[0.221 – 1.027]

* $p < .05$, ** $p < .001$
OR = Odds ratio
CI = Confidence intervals

How do animations and story theme affect children's possibility judgments of story events on e-books?

For this analysis, we excluded the 96 children in the print condition and only included 85 children from the animated and non-animated e-book conditions.

Similar to our procedure above, we created a full model with the following predictors: Children's age (in months), their free recall scores (0-4), their 4 FO construct proportion scores (Cognitions, Toys and Games, Pretense, Entities), Animation (with, without), Theme (realistic, fantastical), the interaction between Animation and Theme, all the 2-way interactions between Animation and the FO constructs, and all the 2-way interactions between Theme and the FO constructs. The model was significant, χ^2 (23, N = 85) = 151.221 $p < .001$, yet we reduced it to achieve parsimony by keeping all the main effects and excluding the non-significant interactions involving the FO constructs. The (non-)significance of predictors did not change. The final model was significant, χ^2 (11, *N* = 85) = 144.94, *p* < .001, and the coefficients are presented in Table 1.3.

The interaction between Theme and Age was significant as earlier, χ^2 (1, *N* = 85) = 12.83, *p* < .001, hence children were less likely to put the fantastical event cards in the "real" box as they got older. Also replicating our previous finding, Theme interacted with Entities, χ^2 (1, *N* = 85) = 5.377, *p* = .02. Children who believed in more fantastical entities were more likely to put cards in the "real" box for the fantastical story. Neither the main effect of Animation, χ^2 (1, *N* = 85) = 0.059, *p* = .808, nor its interaction with Theme was significant, χ^2 (1, *N* = 85) = 0.001, *p* = .975.

Table 1.3

Parameter estimates for the Poisson model predicting the number of cards put in the "real" box in the e-book conditions (N = 85)

	B	*SE*	*OR*	95% CI
Intercept	1.301 *	0.475	3.673	[1.42 – 9.149]
Age	0.004	0.009	1.004	[0.987 – 1.021]
Free recall	0.019	0.062	1.019	[0.899 – 1.148]
Theme = Fantastical (vs. Realistic)	2.311	1.167	10.081	[1.006 – 98.373]
Animation = With (vs. Without)	-0.04	0.161	0.961	[702 – 1.319]
Theme x Animation	-0.012	0.383	0.988	[0.459 – 2.076]
Theme x Age	-0.082 **	0.023	0.922	[0.88 – 0.964]
Cognitions	-0.006	0.221	0.994	[0.638 – 1.52]
Toys and Games	0.092	0.244	1.096	[0.672 – 1.752]
Pretense	0.008	0.18	1.008	[0.709 – 1.438]
Entities	0.008	0.271	1.008	[0.581 – 1.685]
Theme x Entities	1.48 *	0.616	4.394	[1.269 – 14.456]

* *p* < .05, ** *p* < .001
OR = Odds ratio
CI = Confidence intervals

Which factors affect children's categorization of the target causal event as possible?

We ran a logistic regression analysis predicting children's placing the target event card into the "real" box in the card sorting task, which revealed a significant model, χ^2 (8, N = 167) = 37.928, p < .001. Children were less likely to categorize the target event as possible when they read it in a fantastical book compared to realistic, B = -1.087, SE = 0.378, p < .001, OR = 0.337, 95% CI [0.161 – 0.707], and as they got older, B = -0.05, SE = 0.021, p = .021, OR = 0.952, 95% CI [0.912 – 0.993]. The presence of animations or children's FO did not predict their categorization, all p values > .05.

Generalization

The percentages of children who generalized the causal relationship to the real world are presented in Figure 1.3. We found a significant relationship between the six book conditions and children's generalization, χ^2 (5, N = 187) = 13.13, p = .022. According to the pairwise comparisons with Bonferroni adjustments, the only significant difference was between the realistic story on print and the fantastical story on the non-animated e-book, p = .04. It must be noted that each percentage includes preschoolers of all ages. Due to the unequal and insufficient sample sizes for each of the age groups across six conditions, the expected number of observations in cells were not high enough to run the analysis across age groups, unlike previous studies (e.g., Walker et al., 2015).

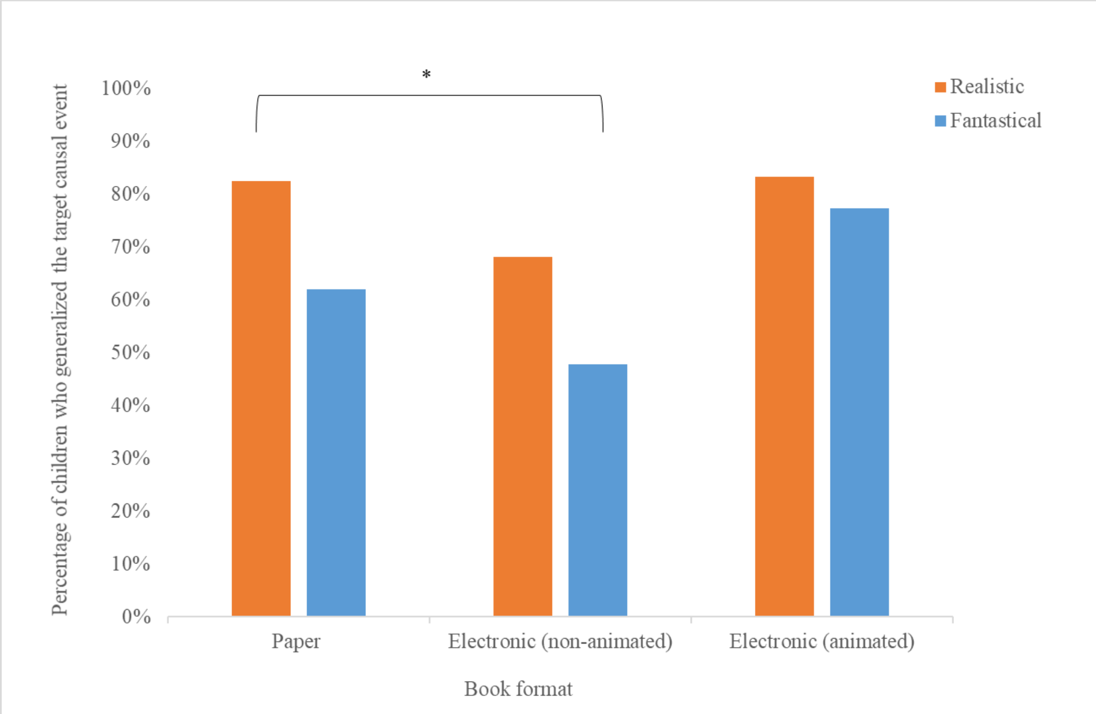

Figure 1.3. Percentage of children who generalized the target causal event. * indicates significant pairwise comparisons ($p < .05$).

For our main analysis of interest, following West, Aiken, and Krull's suggestions (1996), we created two new variables based on our hypotheses by contrast-coding. One variable was to compare the print books combined with electronic books combined (Format). The other variable was to compare the animated and non-animated e-books while excluding the print books (Animation). In line with their suggestions, we also centered all continuous variables at their means to make interpretations easier and to avoid multicollinearity.

For this analysis, 20 children who had missing data for at least one of the FO constructs, and 2 children with missing story recall data were excluded, making the final sample 165 children. We ran hierarchical logistic regression to predict if children generalized (coded as 1) or did not generalize (coded as 0) the target causal event to the real world. We entered our variables in the following steps: (i) the control variables of children's age, their answer to the control generalization question (coded as 0 = did not generalize, 1 = generalized), their free recall scores, (ii) Age x Theme (realistic, fantastical) interaction to replicate previous studies, (iii) our main variables of interest which were children's categorization of the target event (coded as 0 = not possible, 1 = is possible), Format, Animation, and children's scores of four FO constructs.

As can be seen in Table 1.4, the first two steps of our analyses did not reveal significant models, even though the second step was a significant improvement from the first step, χ^2 (2, N = 165) = 7.279, p = .026. In other words, neither our control variables nor the theme of the story was able to explain children's generalization based on our data. The third step was significantly better than the previous one, χ^2 (7, N = 165) = 27.619, p < .001, and revealed a significant model, χ^2 (12, N = 165) = 38.259, p < .001. The model explained 29.7% of the variance in children's generalization (Nagelkerke R^2) and correctly classified 78.8% of cases.

The significant improvement from the previous step indicates that our main predictors of interest explained children's generalization over and above our control variables and the theme of the story. According to this model, theme of the story did not have an effect on generalization. However, children were more likely to generalize the novel causal information when they put the respective event card into the "real" box instead of the "fantasy" box. The odds of generalizing the causal event was 7.4 times greater for children who categorized that event as possible than those who categorized it as impossible to happen in the real world.

Format was not a significant predictor, indicating that children's generalization did not differ across print and electronic book formats. However, we observed a difference within the children in the e-book condition. When the e-book was animated, the odds of generalization was 6.3 times more likely. In other words, children who read the animated e-book were more likely to generalize the target causal event compared to those who read the non-animated e-book.

None of the FO constructs were significant predictors of generalization.

Table 1.4

Summary of the hierarchical logistic regression analysis predicting children's causal event generalization (Coded as 0: Did not generalize, 1: Did generalize; N = 165 children)

	Step 1				Step 2				Step 3			
Predictors	*B*	*SE*	*OR*	95% CI	*B*	*SE*	*OR*	95% CI	*B*	*SE*	*OR*	95% CI
Constant	0.749	0.197	2.115		1.074	0.288	2.926		-0.228	0.507	0.797	
Age	-0.004	0.021	0.996	[0.956 - 1.037]	0.043	0.031	1.044	[0.983 - 1.108]	0.034	0.035	1.035	[0.966 - 1.108]
Control question	0.741	0.448	2.097	[0.872 - 5.046]	0.7	0.455	2.014	[0.825 - 4.917]	0.631	0.505	1.879	[0.698 - 5.058]
Recall	0.01	0.135	1.01	[0.776 - 1.316]	-0.001	0.142	0.999	[0.757 - 1.32]	-0.03	0.173	0.97	[0.691 - 1.363]
Theme					-0.528	0.367	0.59	[0.287 - 1.211]	-0.241	0.416	0.786	[0.348 - 1.776]
Theme x Age					-0.091	0.042	0.913	[0.842 - 0.991]	-0.071	0.046	0.931	[0.851 - 1.019]
Target event possibility									2.012 **	0.476	7.479	[2.939 - 19.029]
Format									-0.787	0.484	0.455	[0.176 - 1.175]
Animation									1.851 *	0.604	6.365	[1.948 - 20.797]
Cognitions									0.208	0.638	1.231	[0.352 - 4.299]
Toys and Games									0.649	0.741	1.913	[0.448 - 8.174]
Pretense									-0.283	0.556	0.754	[0.253 - 2.243]
Entities									-1.067	0.691	0.344	[0.089 - 1.333]
Model statistics												
χ^2 (df)	3.361 (3)				10.64 (5)				38.259 (12) **			
Nagelkerke R^2	0.029				0.09				0.297			
-2LL	193.805				186.527				158.907			

* *p* < .05, ** *p* < .001

OR = Odds ratio

CI = Confidence intervals

Discussion

We investigated the effects of the possibility structure of the story, the format on which the story is presented, and the animations in e-books on children's possibility judgments of the story events and their generalization of novel causal information from fiction. We further explored the role of children's fantasy orientation on their judgments and generalization. Below, we review and discuss our findings.

Story Recall

First, we found that children recall more events from a realistic story compared to a fantastical story. Given that the realistic story in our study was based on mundane events without any unusual incidents, this shows that young children indeed rely on the scripts they have when recalling stories (Hudson & Nelson, 1983). Second, when asked to retell the story, children who read the print book mentioned more of the main story elements compared to those who read the non-animated e-book, whereas children's recall did not differ between the two versions of the e-book. This finding contradicts with the studies finding no difference between children's story comprehension of print and e-books. In many of those studies, the e-book was different from the print book in various aspects such as the inclusion of sound or visual effects (e.g., Richter & Courage, 2017; Verhallen & Bus, 2010), whereas the non-animated e-book in our study was the replica of the print book. Therefore, the difference we observed was solely due to the medium.

One interpretation is that when an e-book is stripped of any multimedia or interactive features, it also loses the elements helping children to remember the story elements. Indeed, according to one meta-analysis, children' story comprehension of multimedia e-books are better than their comprehension of print books they read without the help of an adult (Takacs, Swart, &

Bus, 2014). However, this implies that the recall of animated e-book must be higher than the print book, which was not the case in our study. Given that both books were read by the experimenter in our study, the nature of adult scaffolding in both print and e-book was similar, yet children remembered more events from the print than the e-book even though the two books were identical otherwise.

A second interpretation is that children might have been distracted by the novelty of reading a book on a tablet in lieu of paper. While children may pay more attention to e-books, that attention may be directed to the medium due to its novelty instead of the story content, and may not always improve—and even hinder—children's story comprehension (Kucirkova, 2019; Lauricella, Barr, & Calvert, 2014). Although we did not measure children's visual attention (e.g., looking time or pattern) nor their previous experience with e-books, reading stories on a touchscreen device is not a common practice in Turkey. Hence, children in our study may have paid more attention to the story rather than the format when the book was on paper than on tablet, which in turn facilitated their recall of events.

In addition to children' overall recall of the story, we also analyzed children's recall of the target causal event. Children's recall of this information was very low, indicating that the event did not leave a mark in children's minds despite its novelty. One reason may be that the target causal event was embedded in the breakfast sequence, and it was not a standalone event. Hence, children who recalled that the protagonist had breakfast may had implicitly included the causal event in their response. Future studies may investigate children's recall and learning of a novel causal relationship which is a distinct main event in a fictional story.

Possibility Judgments

To our knowledge, this study is among the first investigating children's possibility judgments of events presented in different book formats. The book format did not affect children's possibility judgments, neither did the presence of animations in e-books. Our findings indicate that when the print and electronic books are carefully matched in terms of content and design, neither the book format nor animations influence how likely children think the story events can happen in the real world. Therefore, answering Li and colleagues' (2015) question, children's understanding of fantastical stories does not seem to differ across different media, at least not in the case of print and electronic books.

Children's possibility judgments differed across stories with different themes depending on their age, where older children were more accurate in categorizing events from a fantastical story as not possible to happen in contrast to their younger peers. Hence, regardless of the book medium, children develop a better understanding of story possibility with age (Woolley & Cox, 2007). However, the effect of story theme also depended on children's FO, specifically on their beliefs in fantastical entities and not the other components of FO. Children who believed in more fantastical entities were prone to incorrectly categorize the events of a fantastical story as possible. In previous studies, children from religious backgrounds were found to be more likely to think that characters in fantastical stories are real compared to children from secular backgrounds (Corriveau, Chen, & Harris, 2015; Davoodi, Corriveau, & Harris, 2016). One explanation was that children who grow up with religious narratives have a broader understanding of what can happen because they have more experience with narratives defying the rules of the real world, and because such stories are told in the same manner with realistic stories. Similarly, children who have experience with fantastical entities may also have a broader conception of possibility, as it was illustrated by our findings. This result takes previous studies a step further by showing that it is not only the theme of the story but also children's age and their individual differences, FO specifically, influencing their judgments regarding the possibility of events.

Generalization

First, in contrast with previous studies, the theme of the story did not affect children's generalization. Hence, we did not replicate previous findings showing that children learn better from realistic stories (e.g., Richert & Smith, 2011; Walker et al., 2015) nor from fantastical stories (e.g., Weisberg et al., 2015). It must be noted that before we added our variables of interest into our model, the simpler model with theme did not reach significance. This implies that our control variables and the story theme were not able to explain children's generalization based on our data, which does not give any information about the statistical significance of theme. The theme variable itself was not significant only when we added the main variables and obtained a significant model. Therefore, our main variables explained children's generalization from books over and above the theme of the book.

When the theme was partialled out, children's possibility judgment regarding the novel causal relationship predicted their generalization. Children were more likely to generalize the causal relationship when they judged it to be possible to happen in the real world. This is in line with a previous finding showing that there is a relationship between children's possibility categorization of the causal target event and their generalization of it from a story (Walker et al., 2015). Based on Fisch's capacity model of educational television comprehension, it was theorized that for children to learn new information from television, they must recognize that that information is relevant to and applicable in other settings (Fisch, Kirkorian, & Anderson, 2005). Indeed, children learn new words in a foreign language or unfamiliar cultural elements from television only when they perceive those words and elements as real and not unique to the show, which implies that they are applicable in the real world (Bonus & Mares, 2019; Mares & Sivakumar, 2014). Our study extends these findings to print and electronic books, and to learning of causal relationships.

Second, children's generalization of the novel causal relationship was not different across print and e-books. Hence, just like they can learn new words or concepts from factual print and e-books (Raynaudo & Peralta, 2019; Strouse & Ganea, 2017), children can learn new causal relationships from fictional books, regardless of the book format. Answering Hopkins and Weisberg's (2017) question, our results suggest that the book format does not affect children's learning from fictional content.

Third, children were more likely to make generalizations from an animated e-book compared to an e-book without animations. Hence, similar to word learning (Korat et al., 2014; Verhallen & Bus, 2010), animations facilitate children's learning of new causal relationships from e-books as well. The underlying reason may be that animations in e-books reinforce the encoding of the story by connecting the visuals and narrative more firmly, hence facilitate story comprehension and learning (Bus, Takacs, & Kegel, 2015; Smeets & Bus, 2015). While we did not find an effect of animations on children's story recalls, indicating that in our study animations did not influence children's memory of the story but only their learning, children's story recall is related to many cognitive skills such as executive functioning and language skills (Richter & Courage, 2017). Even though we did not measure them, children's cognitive individual differences may have influenced their story recalls over and above the effect of animations.

Furthermore, our methodology does not allow us to differentiate the effects of animating all the events in the story from only animating the target causal event. Hence, we do not know if animations increase children's likelihood of generalization because the whole story was dynamically depicted or just the target event.

Last, unlike what some researchers suspected (Mares & Sivakumar, 2014; Walker et al., 2015), we did not find any evidence for FO affecting children's generalization. This contradicts with one previous study showing that children with higher FO are less likely to transfer information from a fantastical story (Richert & Smith, 2011). However, our design differed from Richert and Smith's (2011) in several ways. First, unlike their study, we did not create a composite FO score since the four FO constructs were not correlated. Second, we measured children's causal relationship generalization and not their transfer of problem solutions. Third, we had many other variables of interest which could account for any effect FO constructs could potentially have, such as children's judgment regarding the possibility of the target causal event.

Conclusion and Future Directions

This study investigated preschoolers' possibility judgments of stories and learning from fiction across different story themes and book mediums. We summarize our main findings below and make suggestions for future studies.

To begin with, children learned the novel causal relationship both from print and e-books when they thought that that relationship could happen in reality, regardless of the possibility of the story. In other words, it was not the objective theme induced by us researchers, but the subjective conception of the target event affecting children's learning. Future studies may investigate the child-related factors affecting children's reality judgments of a new piece of information and their learning as a result. Which cognitive factors make children think that a piece of information is real? For instance, children's existing domain-specific causal knowledge (e.g., physical, biological, psychological) may be one factor, given that their prior knowledge in a given domain influences their reality-fantasy distinctions about unfamiliar situations in that domain (Cook & Sobel, 2011). Furthermore, as previous research suggests, children's experience with different media may also affect their learning (Strouse & Ganea, 2017). Future studies may investigate how media experience influences children's learning in addition to their reality status judgments of events presented across different mediums. Last, although we showed that preschoolers can learn from print and e-books, studies with delayed post-tests may consolidate our findings since based on our design, we cannot conclude if children's learning from fiction and from different media persists over time.

Our second main finding was that children were more likely to learn a causal relationship when they read it in an e-book with dynamic and not static illustrations. In our study, the only difference between the animated and non-animated books was the presence of moving illustrations. With such careful comparison, we were able to pinpoint the effects of animations. However, there are three caveats. First, the boosting effects of animations was not only for realistic but also for fantastical stories. More research is needed to understand the cognitive mechanisms underlying this finding. Why is that children are more likely to learn from stories when events are dynamically depicted? Second, there are many other multimedia features e-books can include such as sound effects. Future studies may continue experimentally investigating both the isolated and the combined effects of different multimedia features on learning from e-books. Third, the e-books used in this study were specifically designed for research purposes, which withholds us from generalizing our findings to commercially available e-books. As Lauricella and colleagues (2017) also point out, commercial e-books are not always carefully designed as those that are created by researchers. Hence, the effects of animations may differ across experimental and commercial books.

Finally, in our study, we explored FO as an individual difference variable among many possible others. Children's FO had an effect on their possibility judgments of story events but not on their learning from books. Other individual differences may play a role in children's learning. Given that different FO constructs have different executive functioning correlates (Pierucci et al., 2014), future research may explore if and how executive functioning relates to children's possibility judgments and learning from print and digital media. For instance, attention shifting was found to be correlated with children's interest in fantastical thoughts (Pierucci et al., 2014) and was also suggested to be related with children's reality judgments of television content (Li et al., 2015). Last, while we did not observe any effects of FO on children's learning, future studies must continue investigating by administering more elaborate FO measures.

Considering that fiction is a prominent source of knowledge for young children, understanding their conceptions and learning from stories is important to design effective learning experiences for them. Our findings contribute to that goal by investigating both book-related and child-related factors influencing children's interaction with fiction.

CHAPTER II

LEARNING FROM THE REAL AND THE VIRTUAL WORLDS: EDUCATIONAL USE OF AUGMENTED REALITY IN EARLY CHILDHOOD

Abstract

Augmented Reality (AR) applications are becoming widely available to support preschoolers' cognitive development and education. AR applications with educational features offer an exciting and unique learning experience by blurring the boundaries between the real world that children are in and the virtual world they see on the screen. Nonetheless, effects of blending these two worlds on children's learning and the cognitive mechanisms underlying their learning with AR have not been discussed. To show why and how AR can have a unique contribution to early education, we review research on the ways that realistic and fantastical themes in narratives, and children's making of connections between the real world and the screen affect their learning. In the light of those findings, we proceed to discuss the affordances of AR and provide a set of recommendations for designers. We argue that a well-designed AR application can support young children's learning by (i) drawing children's attention to the learning material and encourage them to reflect on the content by setting an unconventional scene for learning, and (ii) reducing the representational dissimilarity between the context where children learn new information and the one where they need to apply what they have learned. By providing an overview of developmental research on the effects of themes and screens on children's learning, we aim to provide a psychological basis for the development of educational AR products targeting young children.

Keywords: augmented reality, learning, reality-fantasy distinction, screen media, preschool children

Introduction

One of the main motivations of parents for downloading applications for their preschool-age children is to support their learning of new information and skills (Marsh et al., 2015). Blending physical and virtual worlds, *Augmented Reality (AR)* offers a new platform for learning. It is already widely used in educational settings for elementary school, high school, and university students (Akçayır & Akçayır, 2017; Bacca, Baldiris, Fabregat, Graf & Kinshuk, 2014), but its implementation is more complicated for preschoolers due to the fast-developing cognitive abilities of this age group. AR is a technology which plays with our reality perception; thus, one challenge for designing AR applications aiming at young children concerns their difficulty in learning from non-realistic contexts and screens. Considering that preschool years are critical for the formation of academic skills and intellectual development (Campbell, Ramey, Pungello, Sparling & Miller-Johnson, 2002), it is important to explore the educational potential of emerging technologies, such as AR, for young children. In this article, we discuss this potential of AR regarding the relationship between children's reality conception and their learning.

Through a touchscreen device, webcam, or a head-mounted display, AR applications blend physical and virtual worlds (Radu, 2014). In this article, we focus on non-immersive screen-based AR applications where the system overlays computer-generated information to the physical world around the user, through a screen. Unlike other emerging technologies such as social robots and Immersive Virtual Reality (IVR), AR already met the average consumer because it is relatively cheaper, easier, and safer to implement. Social robots have some hardware issues, such as speech recognition, to be ready for the daily use of children (Kanero et al., 2018), and IVR has some psychological and technical constraints, such as being "too real" for children (Bailey & Bailenson, 2017) and motion sickness. They are valuable tools for children's learning, and they may be even better options than AR under certain conditions. Nonetheless, we argue that for the reasons that are expanded in this paper, AR can be an optimal learning tool specifically for children at the preschool years of age.

With AR, users can simultaneously interact both with the real and the virtual worlds. This turns AR into an exciting entertainment and learning tool for children. Books are a prominent source of knowledge for young children, and children's books with AR elements are becoming popular and accessible (e.g., *My Very Hungry Caterpillar AR*, *Ernie's Wish Trail*). In addition to books, there is an increasing number of mobile applications targeting young children's learning in various domains of knowledge. To illustrate, AR applications aim to teach preschoolers about nature (e.g., *Disneynature Explore*, *AR Diorama - Qurious Island*), mathematics and geometry (e.g., *Math Alive*, *Math Ninja AR*, *CyberChase Shape Quest*), geography and the solar system (e.g., *SmartGlobe AR*), and reading (e.g., *Letters Alive*, *Big Bird's Words*). In these applications, children can learn new information with the help of the interaction between the touchscreen and a tangible object, such as cards or a globe. While designers rapidly develop and release such applications to the market, cognitive mechanisms that underlie children's learning from them have not received enough attention.

Hirsh-Pasek and colleagues (2015) proposed four principles for educational mobile applications based on scientific literature. They argue that in addition to explicitly setting a learning goal, an application can have an educational value only when it enables children to actively participate in the process, includes engaging materials, provides children with meaningful experiences they can relate to, and offers a setting for social interaction all at the same time. A well-designed educational AR application can tick all these boxes. First, AR allows children to actively interact both with tangible and digital tools (Marsh et al., 2015). Second, children are observed to be engaged and motivated to learn while using AR (Rasalingam, Muniandy, & Rasalingam, 2014). Third, as an example of meaningful learning, children can relate the information they see on the screen with the familiar physical environment they are already in and with their daily lives (Marsh et al., 2015), instead of being fully immersed to a foreign setting as in IVR. Finally, AR creates an environment for children to discuss and play together with their friends (Bodén, Dekker, Viller, & Matthews, 2013). While these criteria apply to educational AR applications as well, there is a need for a cognitive framework which will inform future AR implications with learning objectives. Children's understanding of mixed realities needs to be placed within the framework, the one which must be built through an information exchange between researchers and designers. To ignite this communication, we hereby offer a psychological ground to the educational use of AR targeting preschoolers.

The aim of this article is to uncover the cognitive mechanisms underlying young children's learning with AR by providing an overview of the empirical research on the role of reality on preschoolers' learning. We believe that understanding these mechanisms will inform designers about the affordances and constraints of AR for the targeted age group. Hence, after providing AR examples targeting early childhood education, we address the extent to which the distance between the learning context and reality affects young children's learning, followed by children's transfer of learning from screens to the real world. We then discuss the potential effects of these aspects on preschoolers' learning from AR. Lastly, in the light of research reviewed, we suggest that AR has the potential to contribute to children's learning processes when certain conditions are met.

AR in Early Childhood Education

In contrast to the rapid commercialization and availability of educational AR products targeting preschoolers (Marsh et al., 2017), research is predominantly conducted for older age groups (Akçayır & Akçayır, 2017; Bacca et al., 2014). One review published in 2017 showed that only 1% of the studies targeted preschoolers (Akçayır & Akçayır, 2017). Collapsing findings from all age groups, two reviews revealed that AR increases learning performance, motivation, and engagement of students although it may be difficult to use and may create cognitive overload (Akçayır & Akçayır, 2017; Bacca et al., 2014). Similarly, one comparative review found that students understood the content better, remembered it more, performed better in physical tasks, collaborated more, and showed more motivation when using AR compared to non-AR traditional or digital media whereas problems with attention, usability, and classroom integration occurred (Radu, 2014). Thus, despite its shortcomings, AR seems to contribute to the knowledge acquisition of older age groups.

To our knowledge, there are no systematic reviews on preschoolers' learning outcomes with AR. This poses an obstacle for designers who develop evidence-based AR applications targeting this age group. Here, we provide some examples to illustrate young children's learning gains, and the wide range of domains for which AR can serve in early childhood education. We selected the following examples from journal articles and conference proceedings because they (i) had an explicit teaching goal, (ii) targeted children younger than 8 years of age, (iii) exclusively focused on screen-based AR and no other mixed reality tools, and (iv) tested their design with children.

Literacy—including alphabet and word learning, and story comprehension—is a prevalent domain in AR targeting early childhood (Aguirregoitia Martinez, Lopez Benito, Artetxe

Gonzalez, & Bilbao Ajuria, 2017; Chen, Chun, Lee, & Wu, 2007; Chen, Zhou, Wang, & Yu, 2017; Dalim, Piumsomboon, Dey, Billinghurst, & Sunar, 2016; Motahar, Fatema, & Das, 2018; Pu & Zhong, 2018; Rambli, Matcha, & Sulaiman, 2013; Safar, Al-Jafar, & Al-Yousefi, 2017; Yilmaz, 2016; Yilmaz, Kucuk, & Goktas, 2017). To begin with alphabet learning, one study used AR to draw 5-year-old children's attention to the learning material when teaching letters. By placing markers on the alphabet book, children were able to see the uppercase and lowercase versions of the letters, corresponding objects (e.g., a banana for the letter B), and the way the letter is drawn, all in 3D images overlaid onto the real world around them on a computer screen. Majority of children correctly recognized the letters and they reported high enjoyment (Rambli et al., 2013). Another group of researchers developed a picture book with AR to teach preschoolers Chinese patterns. Their descriptive statistics revealed that children who were trained with the AR book were better in writing, reading, and memorizing the patterns than those who were trained with the traditional book (Chen et al., 2007). Confirming these findings, another study found that 3- to 5-year-old children improved in Bengali letter recognition following a week-long AR use compared to their peers who learned the letters in the traditional way (Motahar et al., 2018). To experimentally investigate the effects of AR on alphabet learning, one study used commercially available AR applications to teach the English alphabet in Kuwait. During the 7-week intervention, one group of preschoolers followed the traditional methods while the other group used the AR applications to learn the letters. The AR group performed significantly better on the achievement test compared to the control group. Furthermore, in the AR group, children's level of communicating with their peers and using their senses throughout the intervention were positively correlated with their achievement test scores (Safar et al., 2017).

In addition to alphabet learning, research has been conducted on preschoolers' learning of new words in first (Yilmaz, 2016) and second languages (Aguirregoitia Martinez et al., 2017; Chen et al., 2017; Dalim et al., 2016; Pu & Zhong, 2018), as well as story comprehension (Yilmaz et al., 2017). In one study, 5- to 6-year-olds were taught words in their native language Turkish with AR-based flashcards, puzzles, and match cards. While children's learning gains were not directly measured, their active interaction with materials (i.e., commenting, questioning) was significantly associated with higher cognitive attainment as indicated by their extensive descriptions of their experience (Yilmaz, 2016). Studies were more frequently conducted for second language learning. Chinese-reared 3- to 6-year-olds were taught English words either with traditional methods or a mobile AR application with which they could scan cards to see the 3D versions of the words and hear their pronunciations. Children were tested three times with regular intervals. At all age groups and testing points, AR group remembered more words than the non-AR group (Chen et al., 2017). Similarly, one study with 5-year-olds raised in Spain found that children's English grades improved following an AR-based curriculum combined with physical activities, videos, and stories (Aguirregoitia Martinez et al., 2017). On the other hand, one study conducted with 3- to 6-year-olds in Malaysia did not find a difference between AR and non-AR desktop applications when teaching colors, shapes, and spatial prepositions, although researchers observed a slight increase in the learning gains of children in the AR group (Dalim et al., 2016). In another study, Taiwanese-reared 4- to 8-year-old children were taught animal, fruit, and vehicle names in English either with an AR game and cards or with traditional cards. The two groups did not differ in their learning gains (Pu & Zhong, 2018). Moving to story comprehension, one study used AR to animate the pages of a print picture book. Five to 6-year-olds were mostly able to remember the time, place, and the consequence of the story while they were not as good in remembering its main theme. Their happiness resulting from their interaction with AR positively correlated with their comprehension (Yilmaz et al., 2017).

Another domain AR is used to teach young children is nature (Bodén et al., 2013; Cascales, Laguna, Péréz-Lopez, Perona, & Contero, 2013; Rasalingam et al., 2014). For instance, researchers grouped 4- and 5-year-olds into two where both groups had access to the same curriculum on animals but only one group consumed the content with AR. The AR group showed markers to the computer webcam to watch and listen about the coats, corporal temperatures, and reproduction of vertebrates. They also had a marker that served as a magnifying glass; for instance, to look closer at the coats of animals. Teachers then evaluated both groups on their knowledge about animals. Although descriptive statistics reflected slightly better learning for children who were in the AR group, the difference between the two groups was not statistically significant (Cascales et al., 2013). In another study aiming to teach about animals, preschoolers showed flashcards to the tablet camera to watch the animals in 3D on the screen. Interviews and observations indicated that children paid close attention to the learning material and enjoyed this unusual way of learning (Rasalingam et al., 2014). A final example is a study aimed to develop an AR-based system where children created origami animals and let the animals interact with the desktop computer to learn about protecting the nature. Researchers observed that 5- to 6-year-old children played the game in line with the learning objective: they used recycling bins and avoided plastic to help animals to survive (Bodén et al., 2013).

Other domains of AR applications targeting young children include but are not limited to spatial skills (Gecu-Parmaksiz & Delialioğlu, 2018), numbers (Bin Tomi & Rambli, 2013), handwriting (Jeffri & Rambli, 2017), and arts (Huang, Li, & Fong, 2016). Except for a few studies on second language learning, studies reported here mostly conclude in AR’s favor, indicating its high educational potential. Unfortunately, many of these studies rely on descriptive statistics and observations. They mostly lack strong control conditions or a detailed description of the existing control condition, and robust statistical comparisons across conditions with appropriate sample sizes. Although many studies compare AR applications to traditional methods, they either do not clearly describe the traditional methods they implemented or they make it difficult to filter out the effects of AR by amplifying those methods with extraneous factors such as physical activities. Furthermore, they do not measure or report long-term learning gains. Indeed, systematic reviews point at the lack of explanatory and causal quantitative research that measure short- and long-term effectiveness of AR in educational settings (Bacca et al., 2014). These shortcomings make it difficult to draw an objective conclusion about the effectiveness of AR in early childhood education.

Nonetheless, covering a wide range of domains, all these studies aim to teach children real information about the real world by enriching it with virtual elements. Importantly, the information to be taught is not immediately accessible to children unless they make the connection between the real world they are in and the virtual world they see on the screen. This raises a question about the role of reality on children’s knowledge acquisition: how do children translate knowledge from different contexts to the real world? To address this question, in the following section, we focus on the role of associating new information with reality on children’s learning.

Reality and Children’s Learning

AR applications offer new information about the real world in a novel context for young children, which is a blended reality with seemingly fantastical elements (Marsh et al., 2017).

Thus, to discuss children's learning from AR, we need to understand if and how they learn from realistic and non-realistic contexts. Furthermore, although many educational AR applications targeting young children are developed for touchscreen devices such as tablets and smartphones, applying new information from screens to the real world is not an easy task for them (Moser et al., 2015). Here, we review the ways which the theme of stories, and the connection children build between what they see on the screen and the real world affect preschoolers' learning.

Learning from Realistic and Non-Realistic Contexts

New pieces of knowledge are often presented to young children in fictional contexts, which vastly vary in their resemblance to the real world. The distance between reality and the story in which information is embedded affects children's learning from stories.

There is considerable amount of research showing the facilitating effects of realism in stories on children's learning. To illustrate, preschoolers are more likely to generalize a novel causal relationship to real life when they read it in a realistic picture book than in a book with fantastical events (Walker, Gopnik, & Ganea, 2015). Similarly, they are more likely to transfer problem solutions to real world when they hear about an analogical solution in a story with a real character compared to a fantasy character (Richert, Shawber, Hoffman, & Taylor, 2009). The same pattern appears in anthropomorphic stories where animals unrealistically behave in human-like ways. Children learn more factual information about unfamiliar animals when they hear about those facts in books with factual language and realistic pictures instead of anthropomorphic language and illustrations (Ganea, Canfield, Simons-Ghafari, & Chou, 2014). Positive effects of realism on learning have not only been shown by comparing realistic and fantastical contents; children's own reality judgments of content also play a role. While children's age affects their comprehension of a foreign word they hear on a television show, this relationship is partially mediated by the extent children judge that language as real or made-up. Hence, children's perception of a language as a real language is partially responsible for their successful learning of new words in that language (Mares & Sivakumar, 2014).

Despite these findings in favor of realism, construct of *mise en place* entails that unexpected elements that defy reality call for more attention to and reflection on the content. According to this view, children can learn new information from fantastical stories (Weisberg, Hirsh-Pasek, Golinkoff, & McCandliss, 2014). Indeed, it was shown that preschoolers learn new words equally well from realistic and fantastical settings, whereas they are better in describing the words when they are exposed to them through fantastical stories and toys (Weisberg et al., 2015). Furthermore, it was argued that violating children's expectations paves the way for learning by improving their memory for the violating information, and prompting children to seek for causal explanations for the violation (Valdesolo, Shtulman, & Baron, 2017). For instance, preschoolers learn the names of objects that violate their expectations compared to those that do not, but only when the objects are central to the violation and not when unrelated to it (Stahl & Feigenson, 2017). Thus, in contrast to findings in favor of realism reported earlier, elements of fantasy and surprise can have a positive impact on preschoolers' learning.

It was argued that one reason underlying the discrepancy across these findings may be because different types and amounts of non-realistic elements influence children's learning in different ways (Hopkins & Weisberg, 2017), and there are studies supporting this argument. For instance, preschoolers were found to remember a problem solution better from a video where fantastical elements were directly related to the solution, compared to videos where such elements were either irrelevant to the solution or videos that did not incorporate much fantastical elements. Furthermore, preschoolers were least likely to apply the solution to real world from a fantasy-irrelevant video, while equally likely from fantasy-relevant and fantasy-low videos (Richert & Schlesinger, 2017). This implies that the relevancy of fantastical elements affects children's learning of new information from a non-realistic context.

In sum, children take the possibility structure of the context into consideration when filtering information. Besides judging the context, children face another challenge. As adults, we can go beyond the medium on which new information is presented (e.g., book, television) and directly judge the factuality of content. However, the medium itself influences children's learning. Hence, we next address young children's learning from screen media.

Transferring from Screens to the Real World

A substantial amount of educational content today is presented on screens and this poses a challenge for young children. Screen media (e.g., television, touchscreen devices) is largely based on video (i.e., moving visual images), which is a symbolic form of communication that conveys information through multiple sensory channels such as auditory and visual (Richert, Robb, & Smith, 2011). Studying young children's learning from video sheds light on their learning from screen media such as electronic books (Troseth & Strouse, 2017) and in our case, screen-based AR applications.

For children to learn from videos, they need to develop an understanding of the representational nature of videos. Thus, they need to comprehend the relation between what is on screen and the real world (Richert et al., 2011). Children younger than approximately 2.5 years of age have difficulties in matching the content of videos with real life due to their inability to form and hold dual representations (i.e., to connect the symbolic role of the object to the actual object itself; Troseth & DeLoache, 1998). In other words, infants and toddlers experience difficulty in understanding what the content of a video (e.g., a giraffe on an animated cartoon) possibly corresponds to in real world (e.g., a giraffe at a zoo), and this results in difficulty in learning from videos, which is termed as *video deficit* (Anderson & Pempek, 2005). However, as they get older, children accumulate conceptual knowledge both about different representations such as videos, and about the dynamics of the world, which enables them to use videos as a source of information (Troseth, 2010).

Applying information to other contexts than video and to the real world is known as *transfer of learning* (Barnett & Ceci, 2002). Memory plays a key role in this process since transfer of learning requires holding a mental representation in memory to be retrieved later in a different context (Barr, 2013). As the context to which the information is applied becomes more dissimilar than the context in which the information was acquired, memory demands increase. As a result, children experience more difficulty in transfer of learning (Barnett & Ceci, 2002). Imitation studies support the presence of this difficulty by showing that for young children, transferring knowledge from a two-dimensional source (e.g., television) to the three-dimensional world is a demanding task and vice versa (Barr, 2010). For instance, children around 2.5 and 3 years of age struggle transferring what they watch on screens to the real world, and this can be explained by young children's poor memory flexibility, which is the ability of retrieving the encoded mental representation in a novel context (Barr, 2013; Moser et al., 2015).

In addition to facilitating factors such as repetition of content and appropriate use of formal features (auditory and visual editing methods; Barr, 2010), children can conquer the difficulty of crossmodal transfer by means of the social nature of learning (Richert et al., 2011). Adults help children to understand the association between what is on the screen and the world around them. For instance, while toddlers have difficulty in learning the names of novel objects from an adult on video even if they hold the object on the screen in their own hands, they do learn them well when their parents show that the object they hold and the object they see on the screen are the same (Strouse & Troseth, 2014). Online video chat technology also assists children in making this connection by offering a contingent social interaction where the on-screen person is able to provide children with immediate, reliable, and correct information (Myers, LeWitt, Gallo, & Maselli, 2016; Roseberry, Hirsh-Pasek, & Golinkoff, 2015).

Thus, in addition to the possibility theme of the narrative, the medium on which that narrative is presented also plays a role in children's learning. Studies on video highlight the importance of the ability to associate the content on the screen with the real world (Troseth & Strouse, 2017). Children need assistance, mostly from an adult, to make this association and to counteract video deficit. AR provides children the opportunity to physically and mentally play with this relationship by giving them immediate and simultaneous access to both physical and virtual information. We argue that this aspect of AR offers an exciting and potentially effective learning realm for young children. In the next section, from a psychological perspective, we discuss the affordances of AR in terms of preschoolers' learning, and explain why AR can become a meaningful platform for early childhood education.

AR's Contribution to Young Children's Learning

As addressed in the preceding section, young children evaluate the distance between stories and reality while learning, and they may experience difficulty in applying new information from screens to the real world. Although AR studies we focus in this article also use screens to communicate new information, the unique relationship AR builds between the screen and the physical environment creates the opportunity for an easier form of learning from screens. While it can be argued that mixing realities can impede learning rather than facilitating it (Wu, Lee, Chang, & Liang, 2013), we suggest that this ability of AR is its strength. More specifically, we argue that (i) AR can draw children's attention to the learning material and promote reflection on it without fully detaching children from the real world, and (ii) AR can assist transfer of learning by converging real and virtual representations in space and time, and reducing the dissimilarity between learning and transfer contexts.

Merging Realistic and Non-Realistic Elements

Children interpret AR as "magic" and "real" at the same time (Bujak et al., 2013; Dalim et al., 2016; Huang et al., 2016; Yilmaz, 2016), and some studies using AR aim to exploit that magical feeling to enhance learning gains (Bin Tomi & Rambli, 2013; Yilmaz et al., 2017). Although further experimental research is needed, some studies where children judge AR as magical argue that they can learn with it (Huang et al., 2016). As discussed earlier, some research shows that preschoolers are more likely to learn from realistic settings compared to fantastical settings (Walker et al., 2015). The mise en place construct suggests, however, that fantastical contexts can draw children's attention to the learning material and encourage them to reflect on it, thus entail learning (Weisberg et al., 2014). Such playful environments set a learning occasion where children are motivated to actively seek knowledge by evoking the necessary cognitive tools to do so (Weisberg, Hirsh-Pasek, & Golinkoff, 2013). A well-designed educational AR application has this potential. This can be accomplished by purposefully and integrally using AR elements towards an educational goal, and by encouraging social interaction during the use.

By superimposing a virtual layer on reality, AR is playful by nature, and playful learning is known to be effective (Weisberg et al., 2013). In one study, 7- to 8-year-olds "learned through play" about marine life with an AR game, and showed a significant improvement in knowledge from pre- to post-test (Lu & Liu, 2015). Nonetheless, AR elements must be relevant and integral to the educational content to not to hinder or disrupt learning by being solely playful. Fisch (2000) argues that for children to learn from media, the distance between the narrative that surrounds the educational content and the educational content itself must be as short as possible, to not to overload or divide children's cognitive resources. Similarly, he argues, the educational content must be at the heart of those computer games with a learning objective (Fisch, 2005). Following this approach, we argue that AR elements must be directly relevant and integral to the educational goal and content.

Previous research points at the importance of properly integrating fantastical or surprising elements into the learning material. For instance, one study found that preschoolers remembered and applied a problem solution better when they watched a similar solution in a video where fantastical elements were relevant to the solution (e.g., an anthropomorphized animal performing the solution) compared to a video where fantastical elements were irrelevant to it (e.g., anthropomorphized animals singing; Richert & Schlesinger, 2017). Another study found that preschoolers learned the names of the objects and actions that violated their expectations and surprised them, compared to objects that behaved expectedly. Importantly, children only successfully learned the words when the object was actively involved in the violation and not when it was a bystander that just happens to be at the scene (Stahl & Feigenson, 2017). These findings indicate that fantastical or surprising elements must be embedded into the targeted piece of knowledge to successfully facilitate learning.

The importance of relevancy and integrality of AR in an application can partially explain why children sometimes show low cognitive attainment while using AR applications. In two studies where AR was used to enrich toys (Yilmaz, 2016) and picture books (Cheng & Tsai, 2014), children predominantly provided plain descriptions of what they saw instead of profound comments on the content, which authors took as an indicator of low cognitive attainment. One reason behind this might be that children were so enthused over AR that they did not have enough cognitive resources left to reflect elaborately on the content. Even though this is a speculation that needs further investigation, when AR elements are used aimlessly or redundantly, children's capability of guiding cognitive effort to the targeted piece of knowledge may diminish. While desultory use of AR may result in low cognitive attainment, it can be better used to direct children's attention to the specific learning-relevant aspects of the application (Radu, 2014). Therefore, AR must not be the focus of the application but a tool that supports the learning objectives.

Even when AR elements are meticulously used, this may not suffice for preschoolers' learning, unless there is a social component. As in fictional books where parents and teachers may contribute to children's learning by emphasizing the parts to be applied to the real world (i.e., educational content) and parts that are not meant to be transferred (i.e., fictional content; Hopkins & Weisberg, 2017), young children need adult guidance to learn that AR provides information about the real world with the aid of seemingly magical features. Humans do not only gather information about the world through their direct interactions with it but also through other people, and this affects their reality judgments. Indeed, children take other people's testimony into account when they judge the existence of the unobservable. For instance, although 4- to 8-year-old children never saw any germs or vitamins before, they judged such scientific entities as real. They also made parallel judgments and explanations for entities that were endorsed by adults such as the Tooth Fairy, although with less confidence. These were in contrast with their judgments regarding equivocal beings such as monsters whose existence they denied (Harris, Pasquini, Duke, Asscher, & Pons, 2006). AR applications can exploit the powerful role of testimony in children's learning by incorporating social interaction into their design. Through social scaffolding, children can comprehend that what they see on the screen is an extension of the real world, akin to a microscope, as opposed to pure magic. Thus, to go beyond the embellishments of AR, children must be guided by adults about the experience.

AR has the unique ability to set a playful learning scene without disconnecting children from the real world, thus preserving the advantages of both realistic and non-realistic contexts on learning which we discussed earlier. This strength can only be actualized by designing applications where AR elements are integral to the learning objectives and by fostering social interaction about the educational content.

Facilitating Transfer of Learning

AR provides access to multiple representations (e.g., visual, auditory, tactile) of a piece of information at the same space and time, which potentially reduces cognitive load during learning (Bujak et al., 2013; Radu, 2014). Furthermore, it can be argued that AR penalizes children less on their dual representation challenges than IVR, in which children are fully immersed into a virtual world (Bailey & Bailenson, 2017). In contrast to IVR, children do not need to constantly hold the representation of the physical world in mind while exploring the virtual world through AR, since they have immediate access to both.

When children learn with AR, their learning and implementation spaces are the same, whether they need to transfer the new information to the real or the virtual world. As we addressed earlier, the discrepancy in the settings of encoding and retrieval of the information impedes young children's transfer of learning (Barr, 2013). AR, on the other hand, has the potential of reducing the distance between these two settings. It simultaneously provides information on screen and in the physical environment. Complementary relationship between these two sources of information requires constant and iterative monitoring of both, and it gives children a unique opportunity to interact with the real and the virtual worlds at the same time. Thus, similar to online video chat discussed earlier, AR is also able offer immediate, reliable, and correct information on the screen. This can help children to bypass the difficulty they experience with transfer of learning across mediums. In other words, AR can shorten the distance between the contexts of learning and transfer by blurring the lines between the 3D real world and the 2D digital world. However, this argument is still to be tested.

Even if support is provided by empirical data, this does not imply that AR alone is sufficient to foster children's learning from screens. Children still need social scaffolding to make the most out of this experience. It was found that when reading AR picture books with their children, parents adopt different roles and communication styles. Children could provide extensive descriptions of the book content only when they jointly interacted with their parents while reading the book, instead of the parent or the child dominating the session or the two having low levels of communication (Cheng & Tsai, 2014). Authors concluded that exchanging ideas on the story and the AR elements with their parents led children to show higher levels of cognitive attainment. Social collaboration around the application is an important aspect of learning not only with adults but also with peers (Radu, 2014). For instance, 2- to 7- year-olds could not solve a key task in an AR application and needed to observe their older peers to achieve it (Bodén et al., 2013). Discovering how the AR application works together with friends contributes to children's engagement and learning since it provides them the opportunity to discuss and collaboratively reflect upon the educational content.

Future Directions and Recommendations

By offering a playful interaction between physical and virtual worlds, AR offers an engaging learning platform for preschoolers. Considering that reducing the distance between the context where new information is learned and the context where it has to be transferred assists learning (Richert et al., 2009), AR has the potential to contribute to young children's learning by merging real and virtual worlds. However, this potential cannot be attained without a mutual flow of information between researchers from different fields and designers.

Questions for Researchers

Rapid commercialization of AR calls for urgent and systematic multidisciplinary research on its academic effects. Psychologists and education researchers need to address theoretical questions which will inform the development of AR applications. How do children conceptualize the intertwinement of real and virtual worlds at different ages? How do individual differences such as children's fantasy orientation affect their understanding and use of mixed realities? How do children perceive this "new" reality? Is it really new, or do they simply judge it as real or fantastical? How does blurring the lines between the real and the virtual affect children's learning? While we have accumulating evidence for children's learning separately in these two modalities as summarized above, we need more information on preschoolers' understanding of mixed realities and its effects on their knowledge acquisition. Furthermore, research is also needed about the domains of knowledge, concepts, and skills that may be more suitable to teach with AR. For instance, it has been argued that books with fantastical themes may be better for teaching children physics than biology and problem solving (Strouse, Nyhout, & Ganea, 2018). Similarly, physical and visual concepts such as spatial skills (e.g., mental rotation) may benefit more from AR compared to abstract concepts (e.g., Baykal, Veryeri Alaca, Yantaç, & Göksun, 2018).

Meanwhile, design researchers need to carry out controlled experiments to investigate children's learning gains with AR. As mentioned earlier, current literature is lacking methodologically strong experiments to study the effectiveness of AR as well as systematic comparisons between AR and other tools targeting preschoolers. It is important to go beyond descriptive statistics and observations, and to conduct empirical quantitative research with AR and other traditional (e.g., picture books) and digital mediums (e.g., electronic picture books) to reveal the unique educational capacity of AR. Furthermore, studies we reviewed were predominantly conducted in classroom settings with teachers. However, children spend a considerable amount of time with their parents during their early years. Studying children's learning outcomes when they use AR with their parents would make a significant contribution to the literature and the market. Research is also needed to disentangle the conditions under which children learn with AR. How should the interaction between adults and children be stimulated while using an AR application? What does AR need to provide for children to help them easily interact with the content? Which features of AR distract children instead of guiding them? In addition to answering such empirical questions, investigation of long-term learning gains of AR systems is also needed. To be able to conclude that AR is an effective teaching medium, we must ensure that knowledge acquired through AR is sustained over time.

Recommendations for Designers

While researchers seek answers to the questions proposed above, designers will continue introducing new educational AR applications targeting young children to the market. To guide them based on the current psychology findings summarized above, we provide a list of recommendations in Table 2.1.

Table 2.1

Recommendations for designers

1. Intertwine the AR elements with the educational goal. One way of doing this is to use AR to give important information that is not otherwise given. (see Fisch, 2005)
2. Make sure that AR elements are not disrupting but fostering learning, i.e., AR is not distracting but directing attention to the learning material. One way of doing this is to exclusively use AR at crucial points that are directly relevant to the learning material, and to use it to highlight the target information. (see Fisch, 2005)
3. Assist children in relating what they see on the screen with their surroundings and daily life, preferably by fostering social interaction. One way of doing this is to use the affordances of AR to encourage children to explore their physical and social environments. (see Hirsh-Pasek et al., 2015)
4. If it aligns with your goals, design not only for one (a single child) but for two or more (a child and peers or adults), so that it inherently stimulates social interaction. One way of doing this is to position AR as a joint attention element, which requires attention and action from more than one person. (see Nussenbaum & Amso, 2016)
5. Enable children to easily interact with the application, so that they can focus on the educational content instead of spending too much time and cognitive effort on the technical aspects. One way of doing this is to consider targeted age group's developmental skills (e.g., fine motor development) and technology-related abilities (e.g., pinching, drag-and-dropping). (see Russo-Johnson, Troseth, Duncan, & Mesghina, 2017)
6. Guide not only children but also adults about the use and the content of the application, so that it stimulates more content-related talk than technology-related scaffolding. One way of doing this to provide some information about AR, as they may have never used it before, and make it easy to use not only for children but also for adults. (see Krcmar & Cingel, 2014)
7. Be aware of novelty effect, so that children's interest in the application does not wear off over time and that learning effects are long-lasting. One way of doing this is to use AR to build characters with which children can build parasocial relationships they want to maintain. (see Brunick, Putnam, McGarry, Richards, & Calvert, 2016)

Conclusion

AR has the potential of becoming a source of knowledge and development for young children. However, empirical research and multidisciplinary communication are needed to make healthy inferences about the effectiveness of educational AR applications. Answers to the questions we proposed will inform designers to develop effective evidence-based AR learning systems for young children, and will inform researchers to have a better understanding of children’s conception of reality, virtuality, and mixed reality. With the support of empirical research, screen-based AR applications carry the potential of accommodating the four pillars of educational applications (Hirsh-Pasek et al., 2015), and creating their own additional benchmarks for both educational and entertaining experiences for preschoolers.

CHAPTER III

CHILDREN'S PERCEPTION OF SOCIAL ROBOTS AS A SOURCE OF INFORMATION ACROSS DIFFERENT DOMAINS OF KNOWLEDGE

Abstract

This study explores children's perception of social robots as a knowledgeable source of information across different domains of knowledge. Three- to 6-year-old children (N = 80) chose between a robot and either a cartoon character or an adult to learn new information in five different domains. Regardless of who the opponent was, children chose to learn from the robot most about machines and least about biology and psychology. In all domains, children's judgments of robots as animate beings affected their choices. The more animate and human-like children judged robots to be, especially perceptually, the more they were likely to choose the robot over the adult to learn new information from. Our findings suggest that preschoolers' treatment of social robots as informants depends on the topic in question and their animacy attribution to robots.

Keywords: social robots, animacy, selective learning, preschoolers

Introduction

Technological advancements such as touchscreen devices and social robots offer new learning platforms for children. With the increasing number of sources of information, choosing the correct source becomes challenging, especially for preschoolers who are maturing in their abilities to select to whom, how, and about what to ask questions (Mills, Legare, Grant, & Landrum, 2011; Wang, Tong, & Danovitch, 2019). Among other sources, social robots are becoming increasingly prevalent as tutors and learning partners for young children (Belpaeme, Kennedy, Ramachandran, Scassellati, & Tanaka, 2018). Social robots are robots that (semi-) autonomously interact and communicate with humans by following the norms, values, and standards common to humans (Bartneck & Forlizzi, 2004). In this study, we investigated whether preschoolers judge robots as more knowledgeable compared to human adults and cartoon characters across different domains of knowledge. We further examined if and how children's attribution of animate properties to robots affect their judgments.

Children Choose from Whom to Learn and What to Learn from Them

When learning new information from other people, children evaluate others' statements and behavior to decide whom to trust. Children prefer to learn from people who are accurate in their past statements, reliable, and familiar, and those who belong to the same group as themselves (Brosseau-Liard, 2017; Harris & Corriveau, 2011). In addition to humans, children regard technological devices as informants as well and subject them to similar criteria. For instance, preschoolers prefer to learn from a computer (Danovitch & Alzahabi, 2013) or a robot (Geiskkovitch, Thiessen, Young, & Glenwright, 2019) which was previously accurate compared to an inaccurate one. Similarly, preschoolers seek information from a socially responsive robot (that directs gaze and body towards the child when speaking) rather than a robot that is not (Breazeal et al., 2016). These examples show that children make conscious decisions to choose the informative one between two digital sources. Children's perception of a digital source as a good informant has consequences for their learning. Preschoolers are more likely to understand a televised cartoon character's solution to a problem and apply it themselves in the real world when they judge that character to be a knowledgeable source (Schlesinger, Flynn, & Richert, 2016).

In general, children trust adults, yet they also take one's specialized knowledge on a given subject into account (VanderBorght & Jaswal, 2009). As they get older, children understand that knowledge is diversely distributed among people and that there is a *division of cognitive labor* in society: Different people are experts on different subjects (Keil, Stein, Webb, Billings, & Rozenblit, 2008). Preschoolers are able to choose the correct expert among others depending on the topic of a question (Aguiar, Stoess, & Taylor, 2012; Kushnir, Vredenburgh, & Schneider, 2013), and they believe an expert in a relevant domain more compared to one in a different field (Lane & Harris, 2014).

Is there a division of cognitive labor among different kinds of agents? Research with adults suggest that adults look out for *agent-task fit* when they seek or trust advice from different agents, indicating that they seek for compatibility between the agent type and the capability to perform a task (e.g., humans for social tasks, machines for analytical tasks; Hertz & Wiese, 2018; 2019). With children, research thus far predominantly focused on their judgments on the knowledge of humans, whereas their judgments regarding the informing capabilities of different kinds of sources are mostly overlooked. Limited work on this issue revealed that children do not differentiate between books and touchscreen devices to learn about different types of information (e.g., trees, today's weather), at least not until 6 years of age when they start choosing tablets over books to learn about time-sensitive information as in today's weather (Eisen & Lillard, 2016). On the other hand, another study by the same researchers revealed that while preschoolers recognize that books can be used for learning, they do not see learning as one of the functions of iPads, TVs, iPhones, and computers at the level adults do. Mirroring their understanding regarding the functions of these tools, preschoolers prefer books for learning about dogs compared to adults who prefer computers (Eisen & Lillard, 2017). There is a discrepancy in findings between these two studies, possibly due to different methodologies. In the first study (Eisen & Lillard, 2016), participants made suggestions to a doll for her learning, whereas in the latter (Eisen & Lillard, 2017) participants were asked to make decisions for their own learning. Regardless, these studies both show that from childhood to adulthood, individuals change in their preferences about where to learn new information from.

Several studies suggest that seeking information from digital sources (compared to humans) and trusting that information indeed follows a developmental pattern. In one study (Noles, Danovitch, & Shafto, 2015), when given the options of a human adult and an internet search engine (both presented on a computer screen) to learn about unfamiliar animals, adult participants predominantly chose the search engine, and this preference was significantly more than it was for 4- and 5-year-olds. On the other hand, when they were asked to endorse the responses of either informant (as an indicator of their trust), both 5-year-olds and adults endorsed the responses provided by the search engine more while 4-year-olds did not endorse either informant. Children's developing understanding of the limitedness and unreliability of human capacity were considered as the possible reasons for this developmental difference. In another study (Wang et al., 2019), when asked to endorse trivia information (e.g., the color Americans like the best) coming from an unspecified internet source, a teacher, or a peer, 5- to 6-year-olds did not show any preference between the informants, 7- to 8-year-olds endorsed the teacher over the internet, and adults preferred the internet or the teacher over a peer. When the questions were about scientific and historical facts instead of trivia, both child groups asked and endorsed the internet and the teacher over a peer whereas adults preferred the internet over a teacher. These studies suggest that technological informants become more trustworthy sources of information from childhood to adulthood.

As illustrated by Wang and colleagues' study (2019), the subject of the question in hand affects children's preference for informants. Research summarized above either differentiated topics of knowledge in different ways, as in general and time-sensitive in Eisen and Lillard's study (2016) or just focused on one topic, as in animals in Noles and colleagues' study (2015). One way of clustering knowledge is disciplines where each one has its own principles, as in the branches of natural and social sciences (Keil et al., 2008). For instance, as adults, we differentiate the fields of biology and physics, and we have assumptions about the experts in these fields. We expect a biologist to know more about genetics compared to a physicist, even if genetics is not the biologist's exact area of specialization. Likewise, starting from 5 years of age, children expect someone who has a specific piece of knowledge in a specific discipline to be knowledgeable about another piece of knowledge within the same discipline (Keil et al., 2008). In other words, they develop an understanding of expertise based on disciplines.

Studies thus far fall short of providing insight into the role of formally structured ways of clustering knowledge, such as disciplines, on children's selection between different kinds of informants. Do they assume a specific kind to be an expert in some domain than another? For instance, do preschoolers inherently perceive a digital device as more knowledgeable about physics than biology? If so, why? Studies with adults suggest that *humanlikeness* (i.e., similarity to humans as in appearance or skills) may play a role. Adults prefer to seek advice from a human for completing social tasks, and from a computer or a robot for completing analytical tasks, due to the dependence of perceived expertise on the kind of the informant (Hertz & Wiese, 2019). This suggests that perceived expertise is related to humanlikeness of informants as an indicator of their skills necessary to successfully perform different tasks. Social robots offer an interesting tool to answer our question because they are *kind-fluid* in the sense that defy the categorization between machines and humans (Saylor, Somanader, Levin, & Kawamura, 2010). This allows for the experimental use of robots to see the effect of one kind-related characteristic, namely animacy, on children's learning selectivity across disciplines.

Children Attribute Animacy to Robots, to a Certain Extent

Adults are a prominent source of information for children, and cartoon characters are ubiquitously used in educational TV programs and mobile applications. Compared to adults and cartoons, social robots are recently begun to take place in educational settings (Belpaeme et al., 2018), they are more novel to children (Kanero et al., 2018), and unlike the other two, social robots defy the boundaries between animacy and inanimacy (Saylor et al., 2010).

Among these three sources of information, humans are animate and real whereas both robots and cartoon characters are seemingly animate, but robots are real and cartoon characters are not. Regardless, educational TV and mobile applications often pose cartoon characters as if they are real by illustrating them as animate and interactive, as is the case with *Dora the Explorer* breaking the fourth wall by asking questions to the viewer and pretending as if she hears the answer. Similar to cartoon characters like Dora, personified intelligent characters that can interact with children and their environment may contribute to children's learning (Brunick, Putnam, McGarry, Richards, & Calvert, 2016). With their physical embodiment, and anthropomorphic looks and behavior, social robots have more advantage over cartoon characters in establishing a relationship with children and facilitating their learning. However, this advantage is not evident, as robots are complex entities that blur the line between animate and inanimate. They are essentially inanimate machines but they have human-like characteristics such as their humanoid looks and seemingly autonomous behavior which makes them look as if they are animate (Saylor et al., 2010). Children as young as 3 can make a distinction between animate and inanimate entities based on their biological features, yet they struggle in distinguishing the two based on other features (e.g., psychological) and for atypical entities such as robot dogs (Jipson & Gelman, 2007). Although preschoolers have a relatively clear understanding of the animacy status of familiar entities such as a girl or a camera, they do not show a reliable categorization of robots (Saylor et al., 2010).

Acknowledging their complex nature, robots were suggested to form a new ontological category (Kahn, Freier, Friedman, Severson, & Feldman, 2004; Kahn et al., 2011). There is accumulating evidence showing that children place robots on a continuum rather than a dichotomy of animateness and inanimateness (Kory Westlund & Breazeal, 2019; Severson & Carlson, 2010). Factors such as the appearance of the robot, its verbal and nonverbal responsiveness, and its autonomy in its movements can affect children's perception of robots as animate (Cameron et al., 2017). However, animacy is a complex term that may include perceptual, psychological, social, and moral capabilities. An entity might be alive but may lack social properties, such as plants. This poses a challenge for children to judge the animacy status of social robots that are seemingly animate but inherently inanimate.

Prior experience plays a role in creating a unique category for social robots. Among 4- to 7-year-old children who did not have any or had little opportunity to learn about robots (e.g., through museums, media, toys), those who think robots are alive attributed more intelligence (e.g., ability to learn, think, plan) and psychological characteristics (i.e., having emotions and volition) to robots than those who think robots are not alive (Bernstein & Crowley, 2008). On the other hand, for children who had an opportunity to learn about robots, there was not such a relationship between the life status of a robot and its intelligence. With increasing experience with robots, children attributed more intelligence and less psychological characteristics to robots, which is an indicator of treating robots as a unique intellectual entity (Bernstein & Crowley, 2008). As children get older, they also develop a more complex view of the moral, social, and mental characteristics of robots (Kahn et al., 2012).

The ways in which children's perception of informants as animate beings reflect on their learning preferences from those informants had not yet received much attention. Akin to adults taking the humanlikeness of an informant into account when seeking or trusting information (e.g., De Visser et al., 2012; Hertz & Wiese, 2019), children may also consider the animacy status of an informant when faced with different options of informants.

The Present Study

In this study, we sought to understand how children's animacy attributions to robots affect their judgments of robots as a source of information across different domains of knowledge and compared to other kinds of informants (i.e., cartoon characters and adults). We asked three questions: (i) Do children perceive robots as more knowledgeable in certain domains of knowledge than others? (ii) Do children perceive robots as better sources of knowledge compared to other informants, i.e., cartoon characters and human adults? (iii) If and how does attributing animate properties to robots affect children's perception of them as a source of information compared to other informants? To that end, we asked preschoolers to choose one of the two informants (i.e., robot versus either human adult or cartoon character) to answer questions in the domains of physiology, biology, psychology, language, and machines. We expected that (i) preschoolers perceive robots as knowledgeable about physics and machines but not about human-related fields of biology, language, and psychology, (ii) preschoolers perceive robots as more knowledgeable than cartoon characters but not more than adults, and (iii) preschoolers' perception of robots as animate beings affect their preference for robots over other informants. This study goes beyond previous research by pitting robots against other kinds of informants for different disciplines and by investigating the direct relationship between children's attributions of animacy and knowledge to robots.

Method

Participants

Participants were 80 children between the ages of 39 and 75 months (*M* = 56 months, *SD* = 9.24 months; 38 girls), which is the age range widely studied to investigate preference for different technological informants (e.g., Eisen & Lillard, 2017; Noles et al., 2015). Children were recruited through local preschools in Istanbul, Turkey. Two additional children who declared that they saw the NAO robot before and one additional child who did not want to continue the study were excluded.

Materials and Design

Informant selection task. In this task, we asked children to choose the most knowledgeable informant between two options to answer a list of questions. One of the two informants was the robot for all participants. An image of the NAO robot, which is a humanoid robot widely used in educational settings with children (Belpaeme et al., 2018), was used to represent the robot informant. Children were randomly assigned to one of the two opponent conditions. In the Human condition, the robot was pitted against a human female adult (based on a category of a familiar source of information for children: preschool teachers who are predominantly female in Turkey and mothers) whereas in the Cartoon condition, the robot was pitted against an anthropomorphic, animal-looking cartoon character (see Figure 3.1). None of the images of informants were familiar to children. Children were shown a photo of NAO and the opponent, and were asked if they ever saw them either on screen or in real life. Those who answered affirmative were excluded.

(a)

(b)

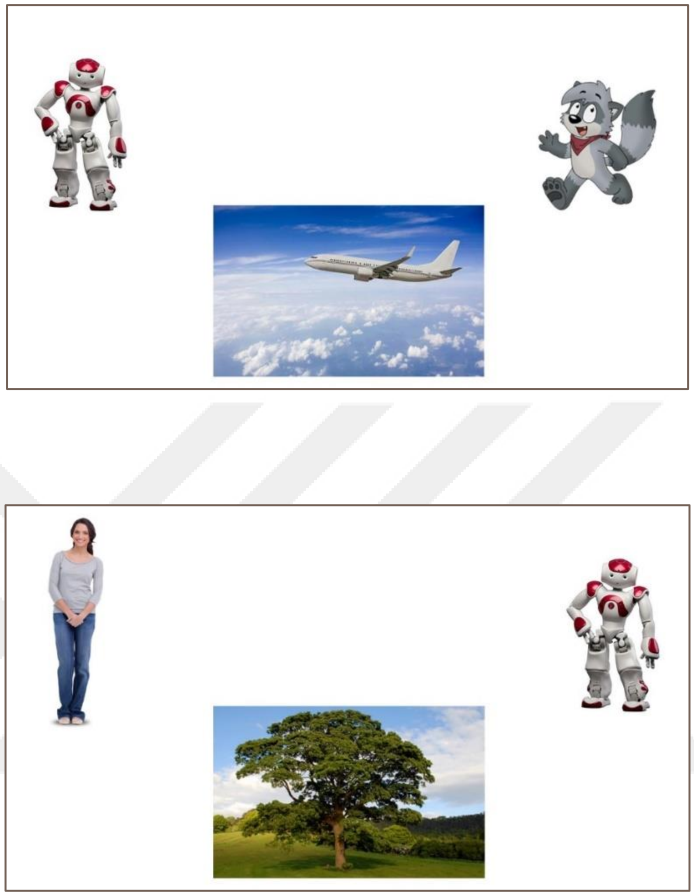

Figure 3.1. The screen layout examples for (a) cartoon and (b) human condition

Children were asked five different questions for each of the five domains, which were Biology, Language, Machines, Physics, and Psychology, totaling to 25 questions. For the domains of Biology, Physics, and Psychology, they were all *why* and *how* questions. For the Language domain, we displayed a word in Vietnamese, Korean, Albanian, Japanese, or Hawaiian; where all but the latter were visibly non-Turkish either because of the non-Latin alphabet or the accents that do not exist in the Turkish alphabet. The question was “What does this word mean?” for three words and “Which language is this word?” for the remainder two. For the Machines domain, children were shown an unusual device such as an industrial drilling machine or a communications receiver. The question was “How does this machine work?” for three and “What does this machine do?” for the rest. For each question, an image that is related to the question (e.g., a plane for the question “How do planes fly?”) was presented along with two informants, according to the condition of the participant. Stimuli can be seen in Appendix C.

Stimuli consisted of 25 items presented as triads of color images on a laptop screen. One photo related to the target question was displayed at the bottom center and the two informants were at the left and right upper corners (see Figure 3.1). For instance, for the question “How do planes fly?”, children saw the photo of a plane at the bottom center of the screen, the robot on one of the upper corners, and the opponent (human or cartoon, depending on the condition) on the other upper corner. The location of the two informants was counterbalanced across trials.

In the study, children were first given a brief introduction about expertise. The experimenter told children that when she has questions about different topics, she prefers to ask them to those who are most knowledgeable on the topic. For instance, when she has sports-related questions, she would seek a specific friend’s help whereas when she has car-related questions, she goes to another friend for help. The experimenter then introduced the two informants on the screen saying that today, she can ask her questions to either of the two and that she needs the help of the child to decide whom to ask: “In the game, your job is to help me figure out who should answer each of my questions. I will tell you my questions and you will show me who knows the correct answer to each question. For different questions, either of the two can be more knowledgeable than the other.” Our pilot study showed that when children were asked to whom they themselves would ask these questions, they tended to give the answer themselves (in line with Aguiar et al., 2012) or said “neither” and talked about someone else. To avoid this, similar to Eisen and Lillard (2016), we asked children to endorse one of the two informants to help someone, in this case, the experimenter.

The 25-item long test trials began following this introduction. After reading each question (e.g., “How do planes fly?”), the experimenter asked “Who do you think knows the answer to this question? *This* or *this*?”, pointing at each informant once. When children refrained from giving an answer or said both would know, the experimenter asked, “Who knows better?” Both behavioral (e.g., pointing) and verbal answers (e.g., “the robot”) were accepted.

Animacy properties interview. Following the informant selection task, children were shown a photo of NAO on the laptop screen and were asked eight yes/no questions, which were borrowed from Jipson and Gelman (2007) and translated to Turkish. Through these questions, children’s biological, psychological, perceptual, and artifact (reverse-coded) property attributions to robots were measured (see Appendix D). Based on their answers, a total Animacy score between 0 and 8 was calculated for each child; 0 indicating not attributing any living kind properties at all (i.e., perceiving robots as artifacts).

Data Analysis

We conducted generalized linear mixed effects modeling (GLMM) due to the repeated binary response variable (0 = Choosing the opponent, 1 = Choosing the robot for 25 questions; Jaeger, 2008), using the *lme4* package on R (Bates, Maechler, Bolker, & Walker, 2015).

While building our models, in addition to the fixed effects of interest, we initially included a random slope along with a random intercept to allow the variable Domain to have a different effect for each participant. It led to singular fit, meaning that the model was overspecified and that the data did not support the complexity of the random structure we defined. We originally also included a random intercept for Question, yet it proved to have not enough variance, thus was unnecessary. To achieve a good model fit and parsimony, we ultimately only included a random intercept for participants to account for children's baseline differences in their responses. Results below are robust when a random intercept for Question or a random slope is added.

To answer the research questions below, we included the fixed effects of Age (in months), Domain (Biology, Language, Machines, Physics, Psychology), Opponent (Cartoon, Human), scores of Animacy attribution to robots (0-8), and the interaction between Opponent and Animacy to our model. Children's sex was a redundant predictor, hence excluded for parsimony. Categorical predictors (Opponent and Domain) were effect-coded. Continuous predictors (Age and Animacy) were standardized (i.e., the overall variable mean was subtracted from the individual values, which was then divided by the standard deviation) to avoid multicollinearity and convergence problems. To infer the significance of fixed effects, we conducted likelihood ratio tests to compare models where each fixed effect was singly excluded from the base model (Bates et al., 2015; Jaeger, 2008). This allowed us to see if the subtraction of a predictor significantly reduced the model fit.

Results

Descriptives

The two experimental groups did not differ from each other in terms of children's gender, $\chi^2(1, N = 80) = 0.802$, $p = .37$, or age, $t(78) = 0.821$, p = .414.

Children's mean scores of attributing the four properties (i.e., biological, psychological, perceptual, artifact) to robots can be seen in Table 3.1. Kendall's tau-b correlations revealed a negative relationship between children's age and overall animacy attribution to robots ($\tau b = -0.309$, $p < .001$). Breaking down the animacy score to its subscales, we found that age was negatively related with attributing biological ($\tau b = -0.346$, $p < .001$), psychological ($\tau b = -0.175$, $p = .049$), and perceptual abilities to robots ($\tau b = -0.231$, $p = .01$) but not related to judging robots as artifacts ($\tau b = 0.125$, $p = .164$).

Table 3.1

Mean scores of children's animacy attributions across the four properties

	Mean	Standard Deviation
Biological	0.363	0.601
Psychological	0.925	0.868
Perceptual	1.15	0.695
Artifact	1.338	0.728

Note. Children were asked 2 questions for each property. Hence, the scores range between 0 (i.e., not attributing that property at all) and 2 (i.e., completely attributing that property).

Question 1. Do Children Perceive Robots as More Knowledgeable in Certain Domains of Knowledge than Others?

Analyses revealed that except for Age, all other fixed effects (i.e., Domain, Opponent, Animacy, interaction between Opponent and Animacy) have significant roles in the model. The details of the full model are presented in Table 3.2.

Table 3.2

Results of generalized linear mixed effect model to predict children's selection of the robot (coded as 1) over the opponent (coded as 0) (N = 80)

Fixed Effects	*B*	*SE*	*OR*	95% CI
Intercept	0.123	0.145	1.131	[0.85 – 1.504]
Age	0.143	0.161	1.154	[0.841 – 1.583]
Opponent = Human (vs. Cartoon)	-0.428 *	0.146	0.652	[0.49 – 0.868]
Domain = Biology (vs. Grand Mean)	-0.556 **	0.103	0.573	[0.468 – 0.702]
Domain = Language (vs. Grand Mean)	-0.047	0.102	0.964	[0.782 – 1.165]
Domain = Machines (vs. Grand Mean)	0.642 **	0.106	1.900	[1.543 – 2.34]
Domain = Physics (vs. Grand Mean)	0.190	0.103	1.209	[0.989 – 1.478]
Domain = Psychology (vs. Grand Mean)	-0.229 **	0.102	0.796	[0.652 – 0.971]
Animacy	0.403 *	0.162	1.496	[1.088 – 2.056]
Opponent x Animacy = Human x Animacy (vs. Cartoon x Animacy)	0.323 *	0.146	1.381	[1.036 – 1.839]
Random Effects	Variance	*SD*		
Participants	1.435	1.198		

* $p < .05$, ** $p < .001$
OR = Odds ratio
CI = Confidence intervals

Related to our first research question, we found that Domain significantly improves the model fit, $\chi^2(4) = 60.173$, $p < .001$. This implies that children chose the robot over the opponent depending on the domain to which a question belongs. As can be seen in Table 3.2, compared to the grand mean of all five domains, children chose the robot over the opponent (whether it was cartoon or human) significantly less for the domains of biology and psychology, and significantly more for the domain of machines. This is also illustrated in Figure 3.2, showing the amount of increase and decrease in the predicted log odds of choosing the robot by the variable Domain.

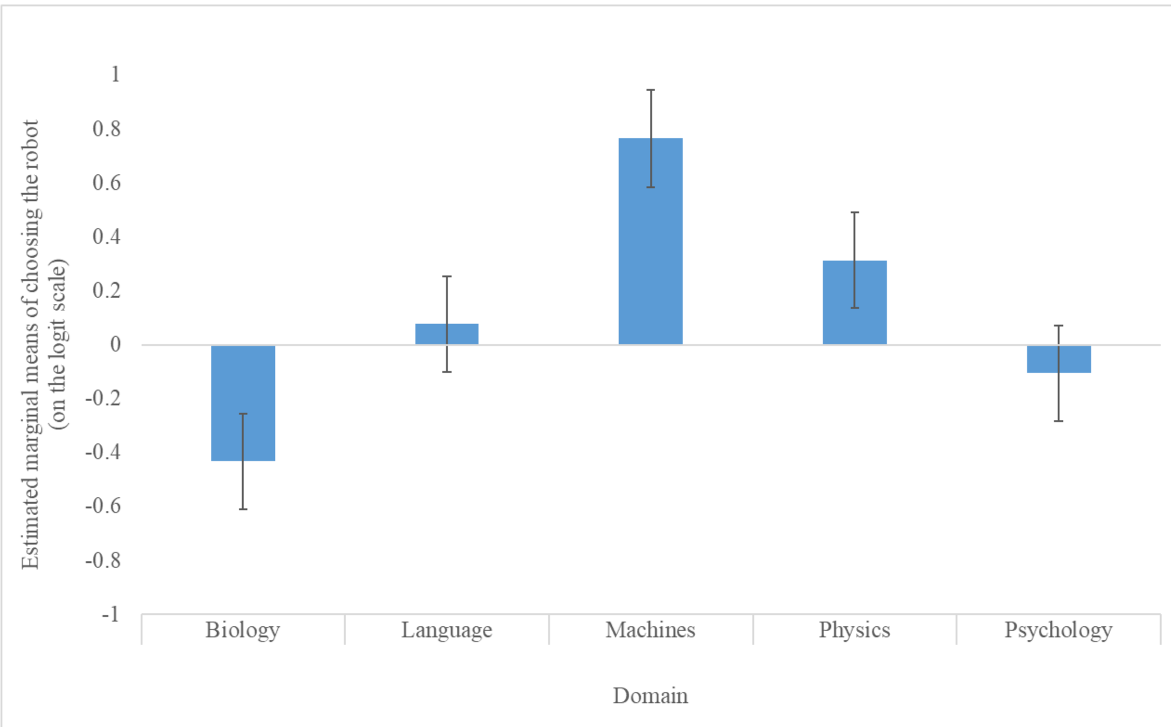

Figure 3.2. Estimated marginal means of children's selection of the robot over the opponent (on the logit scale) across the five domains of knowledge. Bars indicate standard error.

To compare with each other, we conducted post hoc comparisons with Tukey adjustments across the five domains. Averaging the results over the levels of Opponent, children chose the robot significantly more for the Machines domain compared to each of the other domains, which were Biology (B = -1.198, SE = 0.167, p < .001), Language (B = -0.689, SE = 0.165, p = .0003), Physics (*B* = 0.452, *SE* = 0.165, $p = .049$), and Psychology (*B* = 0.871, *SE* = 0.165, $p < .0001$). On the other hand, children had a significantly lower preference towards the robot when the question was about Biology than when it was about Language (*B* = -0.51, *SE* = 0.162, $p = .014$), Machines (*B* = -1.198, *SE* = 0.167, $p < .001$) or Physics (*B* = -0.746, *SE* = 0.163, $p < .001$) but not compared to when it was about Psychology (*B* = -0.328, *SE* = 0.161, $p = .251$). There were not any other significant differences across the domains of knowledge (*p* values > .05).

To make sure that the effect of Domain does not depend on any other factor, we ran two additional models: one with the interaction term between Opponent and Domain (i.e., to see if children chose the robot in a specific domain depending on who the opponent is) and another between Animacy and Domain (i.e., to see if children's animacy attribution affected their choice for the robot in specific domains compared to others). Although the interaction between Opponent and Domain significantly improved the model fit when a random intercept for participants was added, $\chi^2(4) = 19.616$, $p < .001$, this effect did not persist with a more complex random structure where a random slope for Domain was included, $\chi^2(4) = 7.581$, $p = .108$. This implies that the random slope accounts for more variance in children's selection of the robot than the interaction, thus we did not pursue this effect with further post hoc tests. The interaction term between Animacy and Domain did not have a significant contribution to the model, $\chi^2(4) = 4.718$, $p = .317$. In short, Domain did not interact neither with Opponent nor with Animacy, indicating that children chose the robot most for the machines and least for biology and psychology regardless of whether the opponent was a cartoon or a human, and irrespective of their animate property attribution to robots.

Questions 2 and 3. Do Children Perceive Robots as Better Sources of Knowledge Compared to Other Informants? If and How Does Attributing Animate Properties to Robots Affect This Perception?

As can be seen in Table 3.2, Opponent had a significant effect on the model fit, $\chi^2(1) = 7.6882$, $p = .006$), in a way which children chose the robot more frequently when it was pitted against a cartoon character than a human adult. Animacy attribution scores also improved the model fit, $\chi^2(1) = 5.262$, $p = .022$, indicating that the more living kind properties children attributed to robots, the log odds of their preference for robots increased. Importantly, these two effects significantly interacted, $\chi^2(1) = 4.774$, $p = .029$. As Figure 3.3 illustrates, when the opponent was a cartoon character, children' preference for the robot was not affected much by their animacy property attributions to robots. On the other hand, when the opponent was a human, the log odds of children's preference for the robot increased as they attributed more living kind properties to robots. Adding Age to the interaction between Opponent and Animacy did not improve the model fit, $\chi^2(3) = 1.547$, $p = .672$, implying that children's did not change the nature of this interaction.

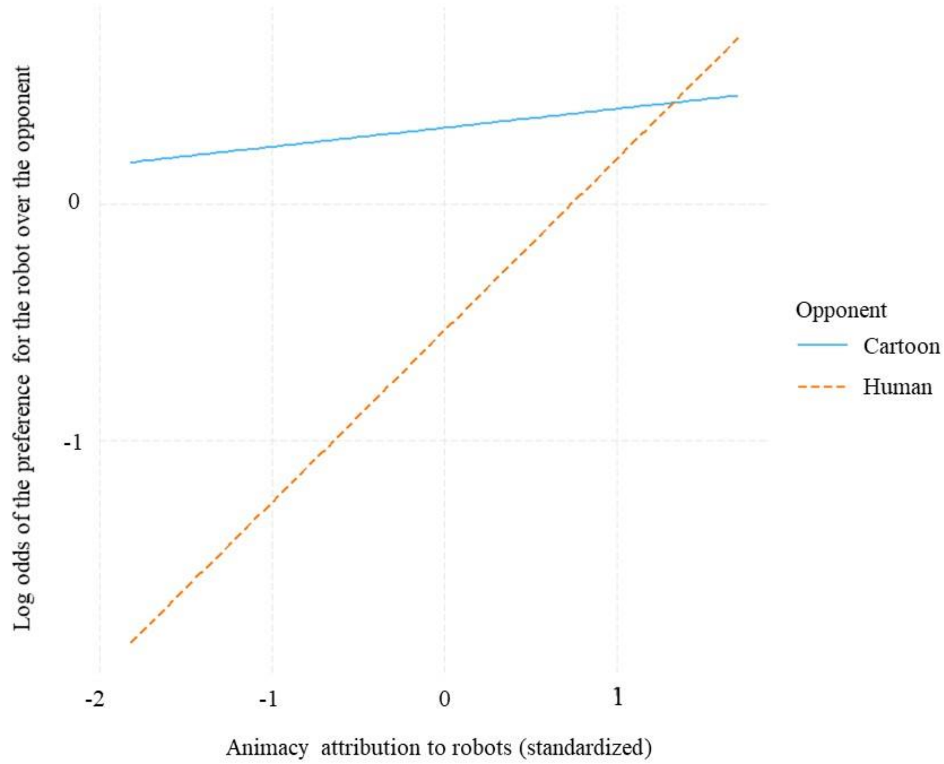

Figure 3.3. Children's selection of the robot as opposed to the cartoon character and the human adult as a function of their animacy attribution to robots.

To understand which subscales drove the effect of animacy attribution on children's choices, we broke the total Animacy scores into its subscales and reran the analyses. The model included Age, Opponent, Domain, and scores of Biological, Perceptual, Psychological, and Artifact property attributions as fixed effects. Analyses revealed that children were more likely to choose the robot over the opponent as they attributed more perceptual abilities to robots *B* = 0.587, *SE* = 0.175, *OR* = 1.799, CI = [1.278 – 2.534]), $\chi^2(1) = 11.069$, *p* = .001. Other subscales (i.e., biological, psychological, artifact) did not have a significant effect on the model fit, all *p* values > .05.

Discussion

In this study, we examined if preschoolers perceive social robots as a source of information across different domains of knowledge, and whether their judgments of robots as animate beings affect their perceptions. Supporting our predictions, children chose the robot over the human and the cartoon to ask questions about machines, but they chose either opponent over the robot to ask biology and psychology questions. Regardless of the domain, children chose the robot over the cartoon but not the human adult to ask questions. However, they were more likely to choose the robot over the human as they attributed more animate characteristics to robots. Below, we discuss our findings in more detail.

Children Perceive Robots as Knowledgeable About Machines but not About Biology and Psychology

Our first main finding is that children perceive robots as a better source of information than humans and cartoons to learn about machines but a worse source to learn about biology and psychology. This selectivity was not dependent on the agent children were comparing the robot against (human or cartoon) or children's attributions of animate properties to robots. Choosing robots to ask about machines but not for biology or psychology is in line with children's judgments of robots as mechanical rather than biological kinds (Severson & Carlson, 2010). Does this mean that children in our study chose the robot to learn about machines because a robot itself *essentially* is a machine? This may be one way of explaining our results, given that complex artifacts such as robots can have an essence like natural kinds do as technological advancements blur the line between natural kinds and artifacts (Gelman, 2013). In other words, choosing the robot most for machines and least for biology may indicate that children believe robots and machines have the same essence, and that this belief guides their choice.

Children's essentialist beliefs may indeed play a role in their knowledge attribution to agents. In line with essentialism, preschoolers know that animals have bones and muscles, and machines have wires and gears inside; thus, they are essentially different kinds (Gottfried & Gelman, 2005). This understanding of internal properties affects children's learning. For instance, 4-year-old children learned the word for a subcategory (e.g., zava) of a familiar animal (e.g., snake) when the two animals shared the same internal properties (e.g., bones, muscles) than when they shared superficial properties (e.g., size, location), implying that internal properties are indicators of an *essence* in living kinds (Diesendruck, 2001). In our study, children might have assumed that robots and machines have similar internal properties, hence they are in the same group. As is the case with children preferring to learn from people who belong to their own group or culture (Brosseau-Liard, 2017; Harris & Corriveau, 2011), because they judged robots to belong to the same group as machines, they may have reasoned that robots are more informed about machines than animal-looking cartoons and humans are.

Our findings about the differences in children's selections across domains do not necessarily mean that children would learn most about machines and least about biology from robots. Preference or endorsement must not be confused with actual learning gains (Koenig & Sabbagh, 2013). In our paradigm, children chose to ask one of the two informants to help the experimenter, but they did not ask questions and receive answers, hence children's actual question asking behavior and learning outcomes were not measured (e.g., recall or generalization of the response). While children's endorsement of technological informants and preference to pose them questions may be in parallel with each other (e.g., Wang et al., 2019), they may also follow slightly different developmental patterns (e.g., Noles et al., 2015). In either case, they do not inform us about the teaching capacity of robots in these domains. On one hand, children's preference may not be related to their learning gains. For instance, although preschoolers reported preference for learning with a robot tutor over a tablet and an adult, they learned new words equally well from all three sources (Kory Westlund et al., 2015). On the other hand, children's endorsement may be in parallel with their learning. Children's reluctance in asking language-related questions to robots in our study may partially explain why robots are not yet fully effective language tutors (Kanero et al., 2018). Future studies must investigate the relationship between children's learning preferences and their learning gains.

Children's Animacy Attributions to Robots Affect Their Perception of Robots as Knowledgeable Sources of Information

Our second main finding is that children chose the robot over the cartoon character but not the human adult. This is in line with previous findings indicating that young children tend to choose adults over technological informants to seek information (e.g., Noles et al., 2015). Importantly, children's preference for the robot over the human adult depended on their judgment of the robot as an animate kind: The more animate children perceived the robot to be, the more likely they were to judge the robot as more knowledgeable compared to the human, whereas animacy attribution did not have an effect when the robot was pitted against a cartoon character. For children with little or no experience with robots, being alive and having intellectual properties go hand in hand, whereas for children with more experience, robots are less alive but more intelligent (Bernstein & Crowley, 2008). Given that children in our study did not have any prior experience with social robots, they might have seen animacy as an approximation to intelligence, which in turn affected their treatment of the robot as a more knowledgeable informant over the human. Furthermore, children in our study were more likely to choose the robot when they attributed perceptual abilities to it. This corresponds with children's developing understanding that knowledge acquisition is related to perceptual access to information (O'Neill, Astington, & Flavell, 1992). In other words, children in our study may have thought that robots can be knowledgeable only if they have the perceptual abilities to access information.

One implication of our finding regarding animacy attribution is that as advancements in artificial intelligence and hardware and software improvements of social robots (e.g., speech recognition) will allow for designing more human-like and autonomous robots, children may be more willing to learn from them. However, while this may hold true for children within the age range of our sample (3 to 6 years), it may backfire with older children. Children older than 9 years of age and adults find robots that are too human-like (in terms of appearance, psychological agency, and perceptual experience) creepy whereas younger children appreciate and expect a robot with mental abilities (Brink, Gray, & Wellman, 2019). Furthermore, animacy does not necessarily entail contingent responsiveness (e.g., timely verbal and non-verbal reactions during an interaction), which is an important factor that facilitates children's learning with robots (Breazeal et al., 2016). Hence, our results do not necessarily imply that building more human-like robots will always have positive effects on children's learning from them.

While children's animacy attribution to robots affected their perception of robots as knowledgeable sources of information, their age did not. In line with previous studies, children's age was negatively related to their animacy attribution to robots (e.g., Saylor et al., 2010) but children's selection of the robot as opposed to other informants was not affected by their age. Our sample consisted of children between 3 and 6 years of age. Some previous studies investigating children's preferences for asking questions to different kinds of informants did not find a difference between 3- to 5-year olds (Eisen & Lillard, 2016), 4- to 5-year olds (Noles et al., 2016), and 5- to 8-year-olds (Wang et al., 2019). Considering that these age groups did differ from adults (Noles et al., 2015; Wang et al., 2019), the developmental shift regarding our research questions seems to occur not during but after preschool years, when children are more likely to be experienced with digital devices and their informing functions.

Future Directions

This study goes beyond previous research by comparing different kinds of informants across a wide range of knowledge areas, and future studies may take our findings even further. First, our results reflect children's conceptualizations of a specific social robot, NAO. Given that children vary in their preferences for different types of robots and their perceptions of them (Peca, Simut, Pintea, Costescu, & Vanderborght, 2014), our paradigm with different robots may lead to different results.

Second, children in our study did not interact with the robot or the other informants nor they watched a video of them but only saw their photos. While this allowed us to isolate the effect of appearance from other cues such as gestures and intonation, children's perception of robots changes as they interact with them in a learning setting (Kory Westlund et al., 2015). Hence, children's learning preferences and animacy judgments may differ with different representations of the informants. Furthermore, because we only showed a photo and did not provide children with any background information about the robot, we do not know how exactly children conceptualized the robot we presented them. They may have perceived it as a robot, a cartoon, a toy or a different entity. Future studies can explicitly introduce the robot and the other informants to children, and provide dynamic representations of them through videos.

Third, we do not know children's reasoning behind their selection of an informant over the other. In our pilot study, we asked children why they selected the informant of choice for each item, but their responses were circular as in "because it's a robot". Akin to children's difficulty in explaining why an expert on a subject would know more about a certain phenomenon over another (Keil et al., 2008), this may also be tacit knowledge, at least for this age group. Future studies may prompt children to learn about the rationale behind their preferences.

In conclusion, this study shows that preschoolers selectively choose whom to consult when given different options of sources to ask about different domains of knowledge. Their attributions of animate properties to an agent also affect their choices. By providing insight on children's conception of robots and seeking information from them, our findings can pave the way for the effective use of robots in educational settings.

General Conclusion

This dissertation aims to contribute towards our knowledge of the factors affecting preschoolers' learning from different technological sources. To that end, we conducted two experiments, which were presented in Chapter I and Chapter III, and wrote one theoretical article which was presented in Chapter II. Chapter I focused on children's possibility judgments and learning outcomes across the digital and non-digital versions of fictional content, Chapter II discussed the cognitive mechanisms underlying children's learning from a digital source, and Chapter III addressed children's judgments of different sources of information. Below, after summarizing the three chapters, we discuss the theoretical and practical implications of our findings.

In Chapter I, we investigated children's possibility judgments of events in books and their generalization from them. To that end, we examined the effects of possibility structure of the story, the medium on which the story is presented, representations of events, and children's fantasy orientation. Our results showed that children's judgments regarding the possibility of events is not influenced by the medium on which the story was presented but by the possibility structure of the story and their fantasy orientation. Furthermore, regardless of them reading the book on print or on a tablet, and regardless of the theme of the book being realistic or fantastical, preschoolers generalize a novel causal relationship from a book when they think that that relationship can happen in the real world. They are also more likely to generalize from an e-book with animations compared to one without. These results indicate that children can learn from e-books and print books alike, yet their learning is influenced by how real they perceive the new piece of information and by the multimedia features of the book.

In Chapter II, we focused on children's learning from a newly emerging kind of screen media than e-books. We argued that Augmented Reality applications carry the potential of being an effective learning tool for preschoolers since they blend realistic and non-realistic elements, and they reduce the distance between children's encoding and retrieval contexts. These are two of the factors facilitating children's learning that Augmented Reality uniquely combines. We invite researchers and designers to work together to incorporate Augmented Reality into children's learning toolbox, and we provide initial guidelines to serve that purpose.

In Chapter III, we proceeded from screen media to a technology with physical presence, namely social robots. We examined if children perceive social robots as a useful source of information across different domains of knowledge and compared to human adults and cartoon characters. Our results revealed that children perceive robots as more knowledgeable informants compared to cartoon characters but not compared to adults, yet they are more likely to judge robots more knowledgeable than adults when they perceive robots as more animate beings, especially with perceptual abilities. Furthermore, preschoolers judge social robots to be the most knowledgeable about machines and least knowledgeable about biology and psychology. Our findings suggest that children treat social robots as informants depending on the subject and their conceptions about robots.

Overall, these three chapters lead to two main theoretical conclusions about preschoolers' learning from technology. First, akin to their selectivity in learning from people (Koenig & Harris, 2005), our findings show that preschoolers are also selective in their learning from technological informants. In other words, they take a critical stance towards the information provided by non-human sources. Specifically, preschoolers are selective when (Chapter I), how (Chapter II), and from whom and what to learn (Chapter III) when faced with digital sources of information. This dissertation provides additional support to the previous studies showing that children are prudent in trusting the information coming from digital sources such as computers, television, and smartphones (Brosseau-Liard, 2017). By expanding those findings to other devices (i.e., e-books, Augmented Reality, and social robots), we show that preschoolers are consistent in their skeptical approach for accepting and seeking information from a wide range of sources of information.

Second, our empirical and theoretical findings suggest that children's aforementioned selectivity is grounded on their understanding and perception of the real world. As we discussed above, children learn by accessing information through people and digital sources, and by selecting when, how, from whom, and what to learn. Our findings further indicate that their selectivity is reality-dependent. Chapter I shows that children learn when they think that the target information is realistic, Chapter II argues that associating children's learning context with reality facilitates their learning, and Chapter III reveals that children are prone to seek information from a technological agent when they judge it to be more human-like, especially with perceptual abilities. In the latter case, considering that the agent was a social robot with an anthropomorphic appearance, being more human-like implies more realistic resemblance to a human. Furthermore, children were more likely to judge the robot as more knowledgeable when they believed that it had perceptual access to the world. Together, these results suggest that preschoolers' learning outcomes and information seeking behaviors are influenced by what they themselves and the informants know and think about the real world.

Our inference is in line with previous research showing that children's prior knowledge about the world affects their trust in other people's testimonies and learning from them. Sobel and Kushnir (2013) suggest that children make inferences about the reliability of a source based on their own prior conceptual knowledge while they also consider new evidence they may obtain during their interaction with that source. Even though many factors such as the strength of their beliefs may lead children to be more receptive (Harris, Koenig, Corriveau, & Jaswal, 2018), they are often reluctant to accept information that is against their own perception and understanding of the world. For instance, preschoolers learn a new piece of information from someone who makes statements in line with what they themselves know instead of someone who makes false statements (Koenig, Clément, & Harris, 2004), and they reject a piece of information which contradicts with what they know, even if it comes from a reliable informant who was accurate in their past statements (Clément, Koenig, & Harris, 2004). While the research reviewed here is based on children's trust in and learning from other people's testimony, our findings indicate that they can be extended to children's selective learning from technology. In other words, children are more open to learn from technological sources when they can associate the information and the informant with the real world that they know and experience.

Based on these theoretical contributions, this dissertation also offers practical implications. As Lauricella and colleagues (2017) point out, new technologies often prompt concern in society, including families, educators, and policymakers, while also drawing interest and creating excitement. By investigating the factors influencing children's learning via their interaction with technology, this dissertation provides a scientific insight into the discussion.

In relation to the first theoretical implication, designers and educators must consider the factors leading to sustainable learning depending on the digital tool. Our findings indicate that preschoolers' learning and information seeking from technological sources is not unconditional but depends on several factors such as multimedia features in e-books (Chapter I), the representation of the educational content in Augmented Reality applications (Chapter II), and the type of information sought as well as the conceptions about the agent in case of social robots (Chapter III). Hence, when the aim is to foster children's learning, the factors leading to successful learning particular to each technology must be taken into consideration.

Our second theoretical implication offers one solution to achieve that goal: When constructing digital learning experiences for preschoolers, the content must allow children to associate what they know about the real world with what they are expected to learn, regardless of the kind of technology in hand. This is indeed one of the pillars of learning from educational mobile applications suggested by Hirsh-Pasek and colleagues (2015). They argue that for an educational application to be useful and sustainable for children's learning, it must create a meaningful learning experience for children by helping them to make connections with their personal experiences and prior knowledge. The three chapters in this dissertation also suggest that preschoolers may learn and seek information from technology when the educational content is grounded on reality and when it signals that the information is relevant to the real world.

This implication is of further importance when the educational value of the technologies addressed in this dissertation is considered. Children can make use of their developing source evaluation abilities both in informal and formal learning settings (Brosseau-Liard, 2017). Thanks to the mobile nature of many digital devices, children today can access information anytime anywhere. They can use these devices for learning purposes in different environments including but not limited to their homes and classrooms, and mobile technology also builds and strengthens the relationship between these learning environments (Lauricella et al., 2017). One way for digital content to be meaningful is when children can relate the educational content to their daily environments (Hirsh-Pasek et al., 2015), and the portability of e-books, Augmented Reality applications, and social robots allows for this. Parents and educators can encourage children to use these devices in different environments of their daily lives, hence help them to make connections between the educational digital content and their physical as well as social environments.

The expanding repertoire of technologies offer new resources from which children can acquire knowledge and skills. To put their potential into effect, the opportunities and limitations of each tool must be studied in relation to child-level cognitive developmental factors. Overall, this dissertation makes the case for the use of technology to foster preschoolers' learning while highlighting the importance of understanding the factors playing role in children's learning with different technologies.

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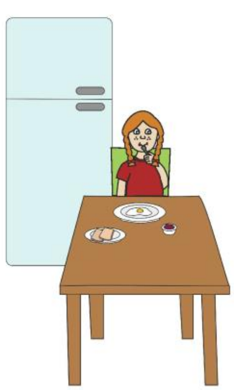
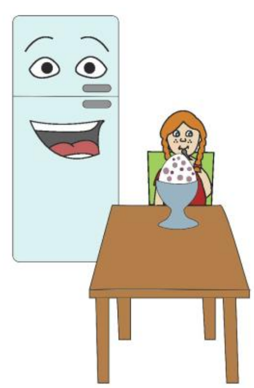
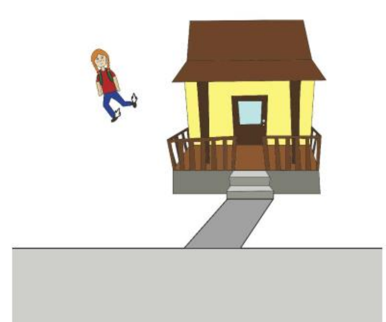
Appendix A

Illustrations of the main events and the target causal event of the books in Chapter I

Realistic Story	Fantastical Story
	
	
	
	

Appendix B

Questions to Measure Children's Fantasy Orientation in Chapter I (Borrowed from Pierucci et al., 2014)

Component	Question
Cognitions	Do you talk to yourself before going to bed?
	What do you think about before going to bed?
Toys and Games	What is your favorite toy?
	What is your favorite game?
Pretense	Do you ever pretend to be an animal?
	Do you ever pretend to be a person other than yourself?
Entities	Are fairies real?
	Are ghosts real?
	Are witches real?

Appendix C

Questions to Measure Children's Selection of Informant Across Five Domains in Chapter III

Domain	Question
Biology	Why do humans sleep?
	Why is our blood red?
	How are trees fed?
	How do animals recover when they are sick?
	How do flowers grow?
Physics	Why does a ball thrown in the air fall back to the ground?
	Why can't we hold a shadow?
	Why is it difficult to walk on a thin rope?
	How do planes fly?
	How can we smell a cake baking in the kitchen from a different room?
Psychology	Why do people help each other?
	Why do people get angry?
	How do people learn how to speak?
	How do people remember what they learn at school?
	How do we hear when someone's calling our name in a crowded and loud playground?
Language	chào bạn
	こんにちは
	aloha
	përshëndetje
	안녕하세요
Machines	  
	 

Appendix D

Questions to Measure Children's Animacy Attribution to Robots in Chapter III (Borrowed from Jipson & Gelman, 2007)

Property	Question
Biological	Does this one eat?
	Does this one grow?
Psychological	Can this one think?
	Can this one feel happy?
Perceptual	Can this one see things?
	If I tickled this one would this one feel it?
Artifact	Did a person make this one?
	Can this one break?