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Identifying Objects Through Touch

A Thesis in Psychology

by

Gabriella Bottalico

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ABSTRACT

People are able to quickly and efficiently identify familiar objects using our sense of touch. Past research has indicated that people are able to do so because they have created mental representations of objects using our senses of sight and touch (Craddock & Lawson, 2009; Klatzky et al., 1985). The objective of this thesis is to provide further insight into the structure (i.e., kinds of perceptual information) included in these object representations. I tested whether the size and prior experience of the objects play a role in our ability to haptically (i.e., through touch) identify objects in a short amount of time. This study had two parts. The first part consisted of 50 participants completing a survey indicating how they typically encounter 40 objects – either by looking or touching. The second part consisted of 130 participants completing a blind identification task in which they haptically identified normative size objects and smaller objects. The objects examined belonged to two categories: those that are typically seen and those that are typically looked at. Participants had either 1 or 5 seconds to haptically explore the objects. Results indicated that participants were more accurate in their responses when they had 5 seconds to haptically explore the objects than when they had 1 second. In addition, participants were more accurate in their responses when they haptically explored objects than those typically viewed. The order in which they first haptically identified the objects, whether first haptically identified objects typically looked at or typically touched, affected their responses as well. Results also indicated that smaller objects are typically haptically identified better when they are typically looked at than those that are typically touched. Implications of these findings are discussed.

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INTRODUCTION

Imagine sitting in class or a meeting. All of a sudden, you hear that familiar ring tone – your cell phone is ringing. You frantically begin searching through your bag. You do not pull out your keys or a book. You are easily able to find your phone without looking. This is not just the case with your cell phone; there are many objects that people are able to identify solely using their sense of touch. How is this possible? Previous research suggests people are able to quickly and efficiently identify familiar objects because they have created mental representations of them by using our sense of sight and touch (Craddock & Lawson, 2009; Klatzky et al., 1985).

When people encounter an object, they access mental representations of the object (Lacey & Sathian, 2015). The information that is a part of these representations allows people to identify the object (Bushnell & Baxt, 1999). An important question to ask is what is the structure of the representations that are being formed and thus being reactivated when being identified through touch? The answer to this question might depend on the type of object. The way that we typically encounter objects on an everyday basis is different for different types of objects. That is, some objects are typically encountered through touch, while others are typically encountered through sight. Do the kind of prior experience people have with different kinds of objects affect our ability to identify them through touch? In addition, objects are often used in their normative size, and in smaller versions of what is typically encountered. Therefore, is size a part of our representation of these objects, and, does it in turn, affect our ability to identify them through touch?

The objective of this thesis is to provide further insight into the structure (i.e., kinds of perceptual information) of these object representations that is optimal for object identification. I will test whether the size and prior experience of the objects play a role in our ability to haptically identify objects in a short amount of time. Before describing the current research in greater depth, I first review literature regarding the haptic system (subset of touch) because knowledge of the haptic system is central to my research questions.

Literature Review:

The Haptic System

It is often assumed that vision is the sole source of object identification (Ernst, Lange & Newell, 2007; James, Kim, & Fisher, 2007). However, as previously seen through your ability to find your cell phone in your bag without looking, touch plays an important role as well. The skin is the largest sense organ on the body. On the average body, it covers about 2 meters and weighs about 3-5 kilograms. It consists of two major layers – the epidermis (outer layer) and dermis (inner layer). There are three systems encompassing the modality of touch – the cutaneous, kinesthetic, and haptic systems. The cutaneous system receives input from mechanoreceptors, specialized nerve endings that respond to force that are embedded in the skin. It is responsible for temperature, texture, slip, vibration, and force. The kinesthetic system receives sensory inputs from mechanoreceptors located within the body's muscles, tendons, and joints. It is responsible for location/configuration, motion, force, and compliance. The haptic system uses combined inputs from both the cutaneous and kinesthetic systems (Klatzky & Lederman, 2002) to coordinate movement and enable perception.

The haptic system enables haptic object identification, the ability to identify objects simply by touching them. People can successfully haptically identify real, common objects in less than 2 seconds and in some conditions have an accuracy rate near 100% (Klatzky, Lederman & Metzger, 1985). People create representations of objects through repeated experience with them. For example, when people touch an object, they activate a representation of that object. The research question motivating this study is are there qualitatively different representations formed through haptic exploration than from visual exploration? Do these representations contain the same kinds of information? If so, what kind of representations enables people to haptically identify objects? My research will provide insight into the structure of the representations and how these representations affect haptic object identification.

Representations

People come in contact with objects on a daily basis. There are some objects that people predominately touch and others that people predominately see. There are competing theories that argue whether the representations formed through visual and haptic exploration are qualitatively different or the same.

There are reasons to believe that there are differences between the visual and haptic representations of objects. Objects that are predominately touched have been called “handmages” (Bushnell & Baxt, 1999). These objects contain information that is easier to obtain haptically than information that can be obtained visually. Attention during haptic exploration might be focused on material-based properties (e.g., texture, mass, rigidity). In contrast, objects that are predominately looked at have been called "eye-mages" (Bushnell & Baxt, 1999). These contain information about the object's shape and color (Klatzky, Lederman & Metzger, 1985).

Bushnell and Baxt (1999) found that qualitatively different representations are formed through haptic experience and visual experience with objects. They conducted an experiment involving 15 children. Each participant completed either a haptic-haptic or a haptic-visual recognition task, in which they first haptically explored objects and then subsequently identified them either haptically or visually. The children were better able to haptically identify those objects that had previously been encountered haptically than they were able to visually identify those objects. The researchers proposed that children were not able to identify objects visually that were initially haptically explored because they did not have a visual memory representation of the object, which would negatively impact the children's ability to successfully visually identify the objects. Results suggest that different representations are created for objects that are predominately touched, "hand-mages," and objects that are predominately looked at, "eye-mages."

Kalagher and Jones (2011) tested participants' ability to complete a cross-modal task. Seventy-two children and 20 adults explored unfamiliar objects either visually or haptically. They then visually identified one of three objects as the object they had previously explored. All age groups chose shape-based matches after visual exploration. Both the 5-year olds and adults also chose shape-based matches after haptic exploration.

Because participants in both the haptic and visual conditions were able to identify the objects by their shape, it can be concluded that qualitatively different representations are not formed from haptic versus visual experience.

Using explicit and implicit memory tests is one way to analyze the representations formed through haptic and visual experience. Explicit memory is measured with recall or recognition tests, whereas, implicit memory is measured with identification tests. Easton et al. (1997) used novel 2-D patterns (e.g., raised lines) and common 3-D objects (e.g., toothbrush, cup) to assess the implicit and explicit memory for vision and haptics. A cross-modal paradigm was used. The participants studied the 2-D patterns in one modality and then were tested either in the same modality or in the other. Implicit memory results revealed that changing modalities had no effect on the participants' ability to identify the patterns and objects. Participants were able to identify the novel 2-D patterns and 3-D objects regardless of how they first experienced the objects. The results provide insight to how objects are best identified. Because the participants performed equally well in the vision-haptics and haptics-vision conditions, it can be concluded that the representations built from visual and haptic exploration are qualitatively similar. However, explicit test results for 3-D objects revealed modality specificity, meaning if they are first given the object visually then they best identify the object visually. The same results were seen when the object was first given haptically. This indicates that the recognition system keeps track of the modality through which an object is experienced. Thus, the explicit test results suggest that the representations are qualitatively different. If this is the case, how objects are typically encountered is how they will best be identifiable.

Neuroscience literature provides conflicting evidence as to whether or not the same cortical regions are activated during visual and haptic exploration (Amedi et al., 2001; Sathian & Lacey, 2007; Stilla & Sathian, 2008). For example, recent research has found that many cerebral cortical regions that are activated during the processing of visual input are also activated during haptic tasks (Sathian & Lacey, 2007). One such region is the lateral occipital complex (LOC), an object-selective region in the *visual* pathway. The left region of the LOC is active during mental imagery (visual imagery) of familiar objects previously explored *haptically* by blind individuals or visually by sighed individuals (Stilla & Sathian, 2008). This region is also active during recall of both geometric and material properties from memory (Newman et al., 2005). If the same brain regions are activated during visual and haptic explorations, then it would be reasonable to assume that qualitatively similar representations are formed following visual and haptic exploration. In contrast, the magnitude of the LOC activation during visual imagery of familiar objects was considerably less than during the haptic exploration of those same objects. This suggests that visual imagery recruits different cortical areas than haptic exploration (Amedi et al., 2001). In sum, previous research provides mixed evidence about whether haptic identification requires prior haptic experience. The goal of this study will be to help resolve the inconsistencies in the literature by manipulating the exploration time, size of the explored objects, and the type of prior experience with the explored objects. This would provide insight into the structure of the representations and how these representations affect haptic object identification.

Haptic Object Identification Variables

Size, time, and prior experience play a role in haptic object identification. Here I will review previous studies that have looked at these three variables. I will be testing the role of each in my experiment.

Size

Size of the objects during haptic object identification is a variable that has been studied (Bigelow, 1981; Ernst, Lange & Newell, 2007; Klatzky & Lederman, 1995; Klatzky & Lederman, 1999). Previous studies (Bigelow, 1981; Craddock & Lawson, 2009) have found that participants were better able to haptically identify objects when they are in their normative size than when they are a different size or a different shape. In one study, Bigelow (1981), tested 24 children's ability to identify miniaturized large objects (e.g., doll's bed), miniaturized small objects (e.g., doll's spoon), and nonminiaturized small objects (e.g., keys). After the children haptically explored each object for as long as they wished, they identified the objects by touch and then by sight. The children were best able to identify the objects that were nonminiaturized. Thus, it is harder to identify objects that are not in their normative size. This suggests that size information is present in mental representations and perhaps plays an important role in object representations.

Another study that found an influence of size change on haptic object identification is Craddock and Lawson (2009). Sixty-one familiar objects were presented haptically. Three exemplars for each category were used. One exemplar had a standard size and shape (coined standard), another had a different size but a similar shape (coined different size), and the third had a similar size to the standard but a different shape (coined different shape). Each standard exemplar had a typical size and shape for an exemplar of that category. Participants were given up to 4 seconds to haptically explore each object. They were instructed to name the objects both quickly and accurately. Results showed that standard (2,952 msec, 8% errors), different-size (3,081 msec, 12% errors), and different shape (3,084 msec, 9% errors) exemplars were all named similarly quickly and accurately. However, there was a trend for different size and different shape objects to be named more slowly – by 129 and 132 milliseconds, respectively – than the standard objects. This showed that it takes longer to identify objects that are changed from their most typical size. This might suggest that size is an important component in the representations people form through haptic experience.

These previous studies (Bigelow, 1981; Craddock & Lawson, 2009) have used objects that were either in their normative size or that were smaller in size. They did not compare participants' ability to haptically identify objects in both sizes. A step further would be to test adult's ability to haptically identify objects when they are in their normative size and also when they are smaller than their normative size. In this current study, objects that are in their normative size and objects that are smaller than their normative size will be tested for haptic identification. Testing participants' ability to haptically identify objects that are in their original size and when they are smaller will provide insight into how our representations of these objects are formed. It will help us understand if it is the object itself or if the size of the object that is essential in their representations. One hypothesis in this study is that objects that are in their normative size will be better haptically identified than objects that are smaller than their normative size. If this result is found, then the object's size plays a role in the representations people form of objects and thus plays a role in our ability to haptically identify them.

Time

Objects can be haptically identified in a short amount of time (Klatzky & Lederman, 1985; Klatzky & Lederman, 1995; Klatzky & Lederman, 1999). For example, Klatzky et al. (1985) assessed adult's haptic identification of hand-size common objects that were readily identifiable through vision. These objects were roughly classified as personal articles, articles for entertainment, food, clothing, tools, kitchen supplies, office supplies, and household articles. Klatzky et al. provided baseline measures of speed and accuracy. Twenty participants took part in this study. Each participant explored 100 common objects while being blindfolded and wearing headphones. They were told to identify the objects as quickly and as accurately as possible. The results showed that 68% of responses occurred within 3 seconds of contact, and 96% of the naming responses were correct. The findings of this study indicate that haptic recognition of real, familiar objects is both fast and accurate.

Klatzky et al. (1985) found that participants were able to haptically identify objects within 3 seconds. These objects consisted of those that were hand-size and commonly touched. However, Klatzky et al. (1985) did not compare how quickly and accurately objects that are not frequently touched can be identified. In my study, objects that are typically touched and objects that not frequently touched will tested for haptic identification in a short amount of time. If participants are able to identify these infrequently touched objects in a short amount of time, this provides insight into what kinds of perceptual information the representations contain. Specifically, it would suggest that the representations formed by previous visual experience are qualitatively similar to those that are formed through previous haptic experience.

Prior experience

The representations people form of objects are created through our prior experience with them, whether it be haptic or visual or both. A number of experimental paradigms have been designed to examine the degree to which representations of prior experience are reactivated. Craddock and Lawson (2009) conducted an experiment that was explained in a previous section. They used an old-new recognition test to examine participant's ability to identify the effect of prior experience on recognition. Thirty participants explored three exemplars of 36 objects. They were allowed to freely haptically explore objects with two hands for up to four seconds. After the four seconds, they were instructed to identify whether the object they held was "old" – previously haptically explored – or "new" – not previously haptically explored. The results indicated that old objects were recognized faster and more accurately than new objects.

Prior experience has also been tested using a paradigm called perceptual priming (Ballesteros, Reales & Garcia, 2007; Blank et al., 1968; Craddock & Lawson, 2009;

Kalagher, 2013). Perceptual priming is giving perceptual experience with an object before completing a cross-modal task. In Blank et al. (1968), children studied a number of objects either visually or haptically. They then were tested for recognition in the other modality. Children did well at haptically recognizing objects that were previously seen but were not good at visually recognizing objects they had previously haptically studied. The authors proposed that representations of information obtained haptically might not be easily used in visual tasks. This provides support for the proposition that representations formed via visual and haptic experience are qualitatively different.

Similarly, Kalagher (2013) measured the effects of perceptual priming on haptic to visual cross-modal transfer. Sixty-two children underwent priming trials where they explored eight unfamiliar objects haptically, visually, or haptically and visually. In the testing trials, the participants haptically explored the objects in the priming trials and then visually identified a match from among three test objects, each matching the object on only one dimension (shape, texture or color). The results indicated that participants in all priming conditions predominately made matches based on shape. The most shape-based matches were made in the Visual and Haptic condition. Because participants in both the haptic and visual conditions were able to identify the objects by their shape, this may be evidence that similar representations are formed from haptic and visual experience.

A continuation of the studies that tested object identification is to test the role of prior experience in objects that are present in everyday life. Studies have used constructed, not real, objects in their testing. For example, Kalagher (2013) tested participants' ability to identify constructed objects visually after being haptically explored. Participants do not have any prior experience with these types of objects, so the structure of the representation is limited. The current study will be testing the role of object identification using real objects that are frequently touched (e.g., stapler, cup, spoon). This will provide insight in the type of prior experience that is reactivated when identifying objects that are familiar to us.

Another continuation of previous studies is to test the role of object identification by comparing objects that are typically looked at to those that are typically touched. The objects that are typically looked at but are not normally touched are those such as a light bulb or an alarm clock. Examples of objects that are typically touched are those such as a pencil or cup. By comparing the kinds of prior experience participants have had with objects, it will be possible to determine what kinds of prior experience are necessary for optimal haptic identification. A second hypothesis in this study is that objects that are looked at on a day-to-day basis, but not entirely touched would not be easily identifiable with haptics alone compared to objects that are typically touched, such as a pencil or cup. If this is the case then the type of prior experience, visual or haptic, people have had with each object matters with regard to identification.

Numerous questions still remain after reviewing past literature regarding haptic object identification. It is still unclear whether the size of the objects being haptically identified play a role in the representations people form of the objects. In addition, it would be helpful to understand if the kind of prior experience (visual or haptic) people has with objects also plays a role in the representations people form. Testing objects of different sizes and different prior experiences for haptic object identification in a short amount of time will provide us with the insight into how people form representations of objects.

Current Research

To test the role of size and prior experience in object identification, the present study consists of testing object identification of objects that are typically looked at and objects that are typically touched, in addition to objects that are in their normative size and smaller than their normative size. There was four object categories: two types of objects and those types of objects in two different sizes. The two kinds of objects being tested are those that are categorized as "Haptic Prior Experience" and "Visual Prior Experience." A Haptic Prior Experience object is one that a person is assumed to have had predominately haptic experience with, such as a spoon and toothbrush. A Visual Prior Experience object is one that a person is assumed to have had predominately visual experience with, such as a light bulb and alarm clock. Testing participants' ability to haptically identify these two different types of objects will provide insight into what kind of representation is being reactivated when being haptically identified.

Additionally, the Haptic Prior Experience objects and the Visual Prior Experience objects were in one of two size conditions: their normative size and smaller than their normative size. The Haptic Prior Experience objects are those that are in their normative size, and the Small Haptic Prior Experience objects are smaller than the objects in the Haptic Prior Experience category. The same is true for the Visual Prior Experience objects.

Participants received two out of the four object categories. They received both Haptic Prior Experience objects and Visual Prior Experience objects, while one category was given in their normative size and the other was given in their smaller size. Time was a between subjects variable, half of the participants explored objects for 1 second, while the other half explored the objects for 5 seconds. Table 1 containing the conditions is provided below.

Table 1: Conditions

1 second	5 seconds
Haptic(n) Visual(s)	Haptic(n) Visual(s)
Visual(s) Haptic(n)	Visual(s) Haptic(n)
Haptic(s) Visual(n)	Haptic(s) Visual(n)
Visual(n) Haptic(s)	Visual(n) Haptic(s)

H(n) = Haptic Prior Experience

H(h) = Small Haptic Prior Experience

Visual(n) = Visual Prior Experience

Visual(h) = Small Visual Prior Experience

My study has two hypotheses. The first hypothesis is that the kind of prior experience people have with an object matters. Therefore, I hypothesize participants will be able to haptically identify objects in the Haptic Prior Experience category better than those in the Small Haptic Prior Experience category. In turn, objects in the Small Haptic Prior Experience category will be identified more accurately than those in the Visual Prior Experience category, in turn being identified better than those in the Small Visual Prior Experience category. Participants are better able to identify objects in the Haptic Prior Experience category because they have the most haptic experience with them than those in the Visual Prior Experience category. If this hypothesis is found, the representations formed through objects people typically touch and objects people typically see are qualitatively different.

On the other hand, a second hypothesis might be that the kind of prior experience participants have had with each object's size is what matters. Therefore, I hypothesize participants will best be able to haptically identify objects in the Haptic Prior Experience category better than objects in the Visual Prior Experience category. In turn, the objects in the Visual Prior Experience category will be better identified than those in the Small Haptic Prior Experience category and then these objects will be better identified than those in the Small Visual Prior Experience category. In short, participants are better able to identify objects in their normative size than those that are smaller because they have more experience with these objects when they were in their normative size. If this hypothesis is found, then size does not play an important role in the representations people form.

METHODS

This study consisted of two parts. Part 1 was a survey created on Google Forms to identify which objects will be used in Part 2. See survey in Appendix A. Participants identified how they normally come in contact with specific objects – either by typically touching them or typically seeing them. See results in Appendix B. The results of the survey determined which objects would be placed in the "Haptic Prior Experience" category, or objects typically touched, and which objects would be placed in the "Visual Prior Experience" category, or objects that are typically seen. See objects in each category in Appendix C.

Part 1: Stimuli Evaluation Study

Fifty participants between 19 and 63 years of age (*M* = 28.54; *SD* = 9.35) completed a survey created on Google Forms. Sixteen of the participants were male. Subjects were recruited through a network of friends and family and did not receive any incentive for participating.

The survey consisted of 42 questions. Participants were asked to provide their age and gender. The remaining 40 questions asked them to indicate how they typically encounter particular objects. Specifically, participants indicated if they typically touch or look at each object during their typical encounters with the objects. They were also given the option of indicating that they had never encountered the object before. The survey can be found in Appendix A.

The results of the survey in Part 1 determined which objects would be placed in the Haptic Prior Experience condition, objects that are typically touched, and which objects would be placed in the Visual Prior Experience condition, objects that are typically looked at. The 40 objects listed in the survey were ranked in order from most frequently encountered by touching to the least frequently encountered by touching. The highest 20 frequently cited objects were placed in the Haptic Prior Experience condition, and the lowest frequently cited 20 objects were placed in the Visual Prior Experience condition. Vase and ashtray were excluded from the Visual Prior Experience condition because they were difficult to find in stores.

Part 2: Experiment

One hundred thirty participants between 18 and 50 years of age (*M* = 19.95; *SD* = 3.99) completed Part 2. Thirteen of the participants were male. Subjects were recruited through the psychology department subject pool and received credit toward their psychology research requirement. The number of participants in each condition is given in Table 2 below.

Table 2: The number of participants in each condition

1 second	5 seconds
Haptic(n) Visual(s) N = 16	Haptic(n) Visual(s) N = 17
Visual(s) Haptic(n) N = 16	Visual(s) Haptic(n) N = 15
Haptic(s) Visual(n) N = 16	Haptic(s) Visual(n) N = 15
Visual(n) Haptic(s) N = 17	Visual(n) Haptic(s) N = 18

For each object in the Haptic Prior Experience and Visual Prior Experience condition, a corresponding object that was roughly half the size of its normative version was used to create two separate object categories. For objects that were smaller than the normative size of the Haptic Prior Experience condition, they were placed in the Small Haptic Prior Experience condition. For objects that were smaller than the normative size of the Visual Prior Experience condition, they were placed in the Small Visual Prior Experience condition. A list of the objects in each condition is included in Appendix C.

Part 2: Experimental Procedure

The participants who completed Part 2 of the experiment sat at a table across from the experimenter. The experimenter explained to the participants that they would be participating in a blind identification task. Participants wore a pair of goggles, the lenses of which were covered with duct tape (to occlude vision). Participants were then instructed to haptically explore each object with their dominant hand for a specified amount of time. Half of the participants explored each object for 1 second and the other half explored each object for 5 seconds. A student research assistant assisted the experimenter in controlling an iPhone app that was used to time the experiment and sounded a beep indicating when time elapsed. At the end of the allotted time, participants were asked to identify the object they held by saying its name aloud. Their answers were recorded.

RESULTS

Part 1: Stimuli Evaluation Study

The survey, given in Appendix A was ranked based on participants' responses from most typically encountered by touched to least typically encountered by touched. The results of this survey are given in Appendix B. The highest 20 objects were placed in the Haptic Prior Experience category, and the lowest 20 objects were placed in the Visual Prior Experience category. Two objects were excluded from the Visual Prior Experience category because they were difficult to find in stores. The objects in each category are given in Appendix C. Implications of these results are explained in the Discussion section.

Part 2: Experiment

Table 3: Mean proportion correct for Prior experience objects divided by Time and separated by the within variables of Size First and Prior Experience Objects First

				Prior Experience First	
			Size First	Visual	Haptic
Time	1	Visual Prior Experience Objects	Small	0.681	0.685
			Normative	0.721	0.693
		Haptic Prior Experience Objects	Small	0.685	0.778
			Normative	0.668	0.882
	5	Visual Prior Experience Objects	Small	0.778	0.733
			Normative	0.809	0.745
		Haptic Prior Experience Objects	Small	0.733	0.803
			Normative	0.803	0.979

The dependent measure in this study was the accuracy of participant's responses to the haptic object identification to prior experience objects (Visual vs. Haptic). Table 3 displays the mean proportion of correct responses in all of the conditions. The proportion of correct responses were calculated because the number of objects in each of the prior experience conditions were unequal. That is, there were 20 objects in the Haptic Prior Experience condition and 18 objects in the Visual Prior Experience condition. Because the numbers were not equal, comparing mean correct responses was not appropriate. Additionally, there were a total of eleven trials that were removed from analysis due to participants using two hands instead of one while exploring the object.

In order to examine differences among these conditions, a repeated measures ANOVA was performed on the scores. However, because it is not appropriate to run an ANOVA on proportions, I transformed the data by calculating the arc sin of the square root of the proportion. The results below used the transformed score, however the proportions are still reported as they make more sense intuitively.

A repeated measures analysis of variance was conducted to compare the effect of Time (1 second or 5 seconds), Prior Experience First (Haptic or Visual), and Size First (Normative or Small) on the accuracy of participant's responses during haptic object identification of prior experience objects (Visual vs. Haptic). All results are presented in Table 4 provided below. I will now discuss each result individually.

Table 4: Results of Part 2

Tests	F scores	Sig
Prior Experience	142.718	.000
Prior Experience x Time	1.822	.180
Prior Experience x Size First	1.931	.167
Prior Experience x Prior Experience First	9.923	.002
Time	35.180	.000
Size First	.101	.751
Prior Experience First	.096	.758
Time x Size First	5.061	.026
Time x Prior Experience First	.027	.869
Size First x Prior Experience First	54.215	.000

The results indicated a main effect of Time, $F(1,122) = 35.180$, $p < .05$. Participants in the 5 second condition gave more accurate responses, $M = 67.343$, mean proportion = .823, than participants in the 1 second condition, $M = 61.409$, mean proportion = .752. This reflects the fact that more time allows participants to fully explore each object, thus enabling them to accurately identify the objects. The main effect was subsumed by a Time by Size First interaction, $F(1, 122) = 5.061$, $p < .05$. This can be explained by the fact that participants in the 5 second condition had more accurate responses when they first explored normative sized objects, *M* = 68.628, mean proportion - .834, than when they first explored smaller objects, *M* = 66.058, mean proportion = .812. In addition, participants in the 1 second condition gave more accurate responses when they first explored smaller objects, *M* = 62.375, mean proportion = .764, than when they first explored normative sized objects, *M* = 60.442, mean proportion = .741. This reflects the fact that when participants have more time to freely explore objects, they are able to explore the entire object. Therefore, they are able to accurately identify objects that are larger. When participants have less time, smaller objects are more easily identifiable because there is less information to be processed.

Additionally, a main effect of Prior Experience, F (1, 122) = 142.718, $p < .05$, was found. Participants were able to identify objects that were in the Haptic Prior Experience condition, *M* = 69.5, mean proportion = .845, better than objects that were in the Visual Prior Experience condition, *M* = 59.251, mean proportion correct = .731. Thus, this finding supports that people form qualitatively different representations during visual and haptic exploration. Also, an interaction of Size First by Prior Experience First was found, F (1, 122) = 54.215, $p < .05$. Participants were better able to haptically identify smaller objects when they first explored objects in the Visual Prior Experience condition, *M* = 67.745, mean proportion = .826, than when they first explored objects in the Haptic Prior Experience condition, *M* = 60.688, mean proportion = 750. Participants were better able to haptically identify objects that were in their Normative size when they first explored objects in the Haptic Prior Experience condition, *M* = 68.373, mean proportion = .825, than when they first explored objects in the Visual Prior Experience condition, *M* = 60.697, mean proportion = 750. This reflects that objects that are typically looked at are better haptically identified when they are smaller in size than when they are in their normative size. The representation of smaller objects has more visual information that is accessible, whereas normative objects have more accessible haptic information. In addition, objects that are typically touched are better haptically identified when they are in their normative size than when they are smaller in size. This suggests that people have more haptic experience with objects that are in their normative size than when they are smaller. This interaction effect supports the notion that people form qualitatively different representations.

There was a two-way interaction of Prior Experience and Prior Experience First, $F(1, 122) = 9.923$, $p < .05$. Participants identified objects in the Haptic Prior Experience condition, *M* = 71.006, mean proportion = .860, better than objects in the Visual Prior Experience condition, *M* = 58.054, mean proportion = .714, when they received the Haptic Prior Experience condition objects first. Participants also identified objects in the Haptic Prior Experience condition, *M* = 67.994, mean proportion = .830, better than objects in the Visual Prior Experience condition, *M* = 60.448, mean proportion = .747, when they received the Visual Prior Experience condition objects first. This suggests that people are better able to haptically identify objects that people typically touch than those objects that people typically see. This may be because people have more haptic experience with the objects we typically touch than those people typically see. Thus, this result supports that qualitatively different representations are formed through haptic versus visual exploration.

DISCUSSION

In this study, I examined how accurately participants were at haptically identifying objects that are typically looked at versus those typically touched, while in their normative size and in a smaller size. The purpose of this research is to see if representations formed through haptic and visual exploration are qualitatively similar or different. Taken together, my results provide strong evidence that time and prior experience are an important factor in our ability to haptically identify objects. In addition, the order in which the objects were haptically explored was relevant as well. Thus, there was strong evidence to support that qualitatively different representations are formed through haptic and visual exploration.

Theoretical Implications

The finding that the amounts of time people have to haptically explore an object affects our ability to accurately haptically identify objects is not unexpected. The participants in this study were able to haptically identify objects more accurately when they had more time. This finding is consistent with the body of research on haptic object identification (Klatzky & Lederman, 1985; Klatzky & Lederman, 1995; Klatzky & Lederman, 1999). Such research found that although people are able to haptically identify familiar objects in a short amount of time, people haptically identify these objects more accurately when they are allotted more time. This current study has similar findings.

Prior research has found that people are able to haptically identify familiar objects faster and more accurately than unfamiliar objects (Craddock & Lawson, 2009). This current study extended research and found that familiar objects that are typically touched are better haptically identified than familiar objects that are typically looked at. Kalagher and Jones (2011) provided possible evidence that similar representations are formed for haptic and visual experience. It was found that children could identify the same objects through touch and vision. This current research provides contradictory evidence. Given that participants in this study were better able to haptically identify objects that are typically touched compared to those that are typically looked at, it can be suggested that when people haptically identify objects they are reactivating their prior haptic experience with them. Therefore, it is a possibility that people create different representations from their haptic versus visual experience with the objects.

In addition, this study supported the findings of Easton et al. (1997). The explicit test results revealed that 3-D objects were best identified in the modality in which they were first explored. My current study found that Haptic Prior Experience objects were more accurately haptically identified than Visual Prior Experience objects because that is how they are typically encountered. Therefore, how objects are typically encountered is how they will best be identified.

One hypothesis of this study was that the kind of prior experience participants have had with each object's size is what matters in the representations people form of the objects. It was predicted that objects in the Haptic Prior Experience and Visual Prior Experience category would more accurately be haptically identified than their smaller size counterparts. This would be consistent with the research indicating that people are able to haptically identify objects better when they are in their normative size (Bigelow, 1981; Craddock & Lawson, 2009). This current study is partially inconsistent with the research. The Haptic Prior Experience objects were better identified when in their normative size; however, Visual Prior Experience objects were better identified when in their small size. This may be the case because people may not take into account the Visual Prior Experience objects' actual size during an everyday encounter because they could be looking at these objects from a distance. Therefore, they look smaller.

In this study, I tested to see if how long participants haptically explore objects, the kind of prior experience they have with objects, and the size of the objects affects participant's ability to haptically identify the objects. Thus, it provides insight into how different representations are for objects that are typically touched and objects that are typically looked at. It was found that all three variables affected haptic object identification. Having more time to haptically explore objects and more haptic prior experience allows participants to haptically identify objects more accurately. In addition, objects in their normative size are best identified when they are objects people typically touch and objects in a smaller size are best identified when they are objects people typically see. In conclusion, people form qualitatively different representations for objects that are typically touched versus objects that are typically looked at.

Practical Applications

The findings of the current research have a number of practical examples. In particular, these findings can benefit occupational therapists sessions with their patients. Occupational therapists help accident and stroke victims relearn how to do a number of tasks involving their hands, such as using a watering can, tying their shoes and using silverware. When providing therapy, occupational therapists can encourage their patients to think about their prior experience with specific objects. For example, as an occupational therapist I can ask my patient to think about their prior experience with a toothbrush when helping them relearn how to brush their teeth. My patient can reactivate their prior experience of touching a toothbrush and enable them to learn how to use this tool. My research can assist occupational therapy sessions and provide more beneficial outcomes for patients.

This research could also be applied to military research in their training exercises. One way the military is currently training their young soldiers is through video games. A specific video game that they use enables them to learn how to use their equipment through an avatar. One lead member of the Raytheon Intelligence, Information and Services commented that people learn better by seeing (Holley, 2014). This research challenges whether or not it is beneficial for soldiers to see their virtual avatar using their equipment or would it be better for the soldiers to physically manipulate the machines because that is how they typically encounter them.

In addition, my research benefits interior car design for car manufacturers. Car manufacturers design cars with buttons and switches that can be operated without having drivers take their eyes off their road. Recently, car manufacturers are experimenting with installing miniaturized buttons and switches in cars. My research provides insight into how representations are formed. This could benefit car manufacturers by suggesting that they think about the formation of representations and deciding if it would be beneficial to miniaturize these operating tools. It would help manufactures understand if making these controls smaller affects driver's ability to manipulate them while driving.

Objects are often used in a miniature form, especially when traveling. Miniature toothbrushes, combs and deodorants are a few examples of objects that are used. Some people travel more often than others, and therefore may use objects in their miniature size more often than when these objects are in their normative size. My research has found that people are better able to haptically identify objects they predominately touch, such as toothbrushes and combs, in their normative size than in a smaller size. This motivates the question of whether using these miniature sized items more often than normative size objects plays a role in the representations people form of objects. This adds to the argument that is later discussed in my Future Directions section with regards to how people may encounter different types and sizes of objects more often than others.

Future Directions

The findings of this study suggest directions for future research. This current study limited participants to haptically explore objects for either 1 or 5 seconds. They were not required to haptically identify the objects in their allotted time frame. Further studies might record participant's response times and compare this across the object and time conditions. In addition, research has found that people are able to haptically identify familiar objects as short of a time as 250 milliseconds (Klatzky & Lederman, 1999). This was not implemented in the current research because it was difficult to find a device or app that could measure less than 1 second. It would be interesting to study participant's ability to haptically identify objects that are typically seen and touched, while also varying in size.

Part 1 of this study required participants to complete a survey indicating how they typically encounter 40 objects – either by touching or looking. It cannot be assumed that objects that were categorized as predominately touched and predominately looked at would be the same for every person. How common an object is encountered predominately by touch or by vision may depend on the person. In addition, how familiar a person is with a particular object can depend on their age, culture, and location. For example, an adult may have more experience with an alarm clock than a teenager due to the use of cell phones being used as an alarm clock. Each of these points can affect how people form representations of objects. These limitations provide insight into how this research can be taken a step further.

Conclusions

In conclusion, the current study provides evidence that there are qualitatively different representations created for objects we typically touch and objects we typically see. The size of the objects plays a role in the representations we form of these objects as well. Thus, the type of objects and size of the objects influences our ability to haptically identify these objects in a short amount of time. This evidence extends previous research on haptic object identification and also provides insight into future research. This research could benefit applications of occupational therapy, military training sessions, interior car design, and more.

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APPENDIX A

Identifying Objects Through Touch

When thinking about your prior experience with the following objects, indicate how you typically encounter each object. Specifically, indicate if you are primarily touching or looking at each object when encountering it most of the time. Please also indicate if you have never encountered the object.

Example: Most of the time when I encounter a key, I am touching it. Although I generally also see the key while I am touching it, I am mostly touching the key. So this item would get marked as "touching."

Example: Most of the time when I encounter a lampshade, I am looking at it. Although you are able to touch a lampshade, you typically wouldn't.

Item	Looking	Touching	Never experienced this object
Spoon			
Shoe			
Vase			
Scissors			
Toothbrush			
Comb			
Cup			
Plate			
Pencil			
Flashlight			
Light bulb			
Hammer			
Tape measure			
Candle			
Glasses			
Picture frame			
Stapler			
Ash tray			
Alarm clock			
Shampoo bottle			
Metal nail			
Paper clip (butterfly and regular)			
Can			
Button			

Battery			
Bar of soap			
Salt/pepper shaker			
Combination lock			
Bowl			
Screwdriver			
Toothpaste tube			
Pot lid			
Paintbrush			
Crayon			
Soda can			
Nail filer			
Band aid			
Chocolate bar			

Appendix B

Object	Percent Touching	Percent Looking
Shoe	77.08%	22.92%
Vase	4.00%	96.00%
Scissors	93.75%	6.25%
Toothbrush	97.96%	2.04%
Comb	87.50%	12.50%
Cup	93.75%	6.25%
Plate	61.22%	38.78%
Pencil	95.83%	4.17%
Flashlight	83.67%	16.33%
Light bulb	6.12%	93.88%
Hammer	83.67%	16.33%
Tape measure	82.61%	17.39%
Candle	0.00%	100.00%
Eyeglasses	60.42%	39.58%
Picture frame	4.17%	95.83%
Stapler	83.33%	16.67%
Ash tray	8.70%	91.30%
Alarm clock	34.04%	65.96%
Shampoo bottle	85.42%	14.58%
Metal nail	29.17%	70.83%
Paper clip	66.00%	34.00%
Can of food	55.10%	44.90%
Button	61.22%	38.78%
Battery	59.18%	40.82%
Bar of soap	95.74%	4.26%
Salt/pepper shaker	73.47%	26.53%
Combination lock	76.09%	23.91%
Bowl	73.47%	26.53%
Screwdriver	89.58%	10.42%
Toothpaste tube	95.83%	4.17%
Pot lid	62.50%	37.50%
Paintbrush	89.36%	10.64%
Crayon	93.62%	6.38%
Soda can	83.67%	16.33%

Nail filer	82.61%	17.39%
Spoon	97.92%	2.08%
Band aid	77.55%	22.45%
Chocolate bar	81.25%	18.75%
Key	100.00%	0.00%
Straw	83.67%	16.33%

APPENDIX C

Objects in "Haptic Prior Experience" and Small "Haptic Prior Experience" conditions:

1) Nail filer
2) Stapler
3) Tape measure
4) Hammer
5) Flashlight
6) Straw
7) Shampoo bottle
8) Comb
9) Crayon
10) Paintbrush
11) Screwdriver
12) Scissors
13) Cup
14) Soda can
15) Pencil
16) Bar of soap
17) Toothpaste tube
18) Toothbrush
19) Spoon
20) Key

Objects in "Visual Prior Experience" and Small "Visual Prior Experience" conditions:

1) Candle
2) Picture frame
3) Light bulb
4) Metal nail
5) Alarm clock
6) Can of food
7) Battery
8) Eye glasses
9) Button
10) Plate
11) Pot lid
12) Paper clip
13) Bowl
14) Salt/pepper shaker
15) Combination lock
16) Shoe

17) Band aid

18) Chocolate bar