The Impact of Cognitive Style on Visuo-Haptic Object Identification

BY

Aidan E.B. Steeves

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Abstract

Haptic and visual object representations in memory rely on similar processes, equating to a multisensory memory trace that is accessible to both modalities. Past research examining the composition of this overlapping memory trace have found evidence for a visual as well as a verbal component. Lacey and Campbell (2006) reported that non-verbal visual distractors impacted the identification of known objects, suggesting a visual component to this shared representation. Contrarily, Desmarais et al. (2021) found that only verbal distractors negatively impact the identification of novel objects, suggesting that this shared memory trace is therefore verbal in composition. Therefore, the question remains: what is this shared memory trace between sight and touch composed of, and does this memory trace depend on the type of object encoded? The current study also examined whether this depends on individual differences in cognitive style, as one's preferred method for obtaining and applying information could explain the conflicting findings of past research. Participants first completed a self-report measure of cognitive style, followed by an object identification task that required them to learn to identify either simple or complex objects, either by sight or by touch. Two-thirds of participants simultaneously completed either a verbal or visuospatial distractor task. Participants learning to recognize complex objects produced more errors and required more blocks to reach criterion compared to those learning simple objects. Participants who completed the task without distraction displayed superior identification performance compared to those who experienced a visuospatial distractor, especially when identifying complex objects. Finally, we demonstrated that the information that composes this overlapping memory representation can be associated with one's cognitive style. However, the degree to which this occurs may depend on the types of objects being learned, as well as the modality in which encoding occurs.

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The Impact of Cognitive Style on Visuo-Haptic Object Identification

Imagine reaching your hand into a bag containing several Christmas ornaments of different size, shape, and texture. Now, imagine you were to select one ornament by touch. If those ornaments were subsequently removed from the bag such that you could now see them, you would likely be capable of visually identifying the ornament you had previously selected by touch, even though you are just now seeing it for the first time. This phenomenon, known as cross-modal identification, is possible because haptic and visual object representations in memory rely on similar processes, creating a shared representation between the two modalities (Desmarais et al, 2017). Despite that, performance is generally superior when learning and testing conditions are the same, a phenomenon known as encoding specificity (Tulving & Thomson, 1973). For visual learning and recognition, this is the case; recognition is superior when both learning and testing conditions are visual (Desmarais et al., 2017). However, when people learn to recognize objects by touch, they perform equally well in visual and haptic identification, violating the concept of encoding specificity (Desmarais et al., 2017). Thus, haptic perception seems to create a particularly rich representation that is also accessible to vision. However, the question remains: what is this shared memory trace composed of? Past research has demonstrated that representations may rely on a visual component (Lacey & Campbell, 2006), as well as a verbal component (Desmarais et al., 2017). One reason we may not yet have a clear answer is because much of the research on this phenomenon has taken a macroscopic approach, neglecting to account for individual differences. For instance, different people tend to process information differently according to their cognitive styles; some people are object-imagers, others spatial-imagers, and some are even verbalizers (Blazhenkova & Kozhevnikov, 2009). In the current study, I examined whether memory traces depend on the types of objects presented, the modality in which they are presented, and the cognitive style of the individual.

Visual and Haptic Identification

Early analyses into haptic and visual identification typically favoured vision, as touch was thought to be inferior to sight (Bryant & Raz, 1975). However, the two sensory modalities are actually quite comparable, with more recent investigations into object recognition having found that, even when controlling for our other senses, touch can be just as effective as vision. Klatzky et al. (1985) reported accuracy rates of 96% when participants were asked to haptically identify common objects, with 94% accuracy occurring within five seconds. These rates are comparable with visual identification, which has been found to yield accuracy rates of 96% for visually distinct objects including clothing and furniture, and 86% for visually similar objects such as fruits and vegetables (Lloyd-Jones & Humphreys, 1997).

Not only are touch and sight comparable in object identification accuracy, the two modalities are similar with respect to the types of information they use to help us perceive our environment. In their investigation into multimodal object categorization, Cooke et al. (2007) had participants perform multiple pairwise similarity ratings for novel three-dimensional objects. Participants first explored the objects either unimodally (haptically or visually) or bimodally, before assigning the objects similarity ratings based on their respective shape and texture. The researchers found that when participants rated the objects using sight alone, shape was the most important factor.

However, those assigned to the haptic or bimodal condition relied on both shape as well as texture when assigning similarity ratings. This demonstrates that the two modalities largely rely on similar sensory information (mainly shape), though touch also perceives and relies on additional perceptual cues, in this case texture.

Wallraven and Gaissert (2012) provide further evidence for the similar processes between touch and sight as they analyzed how people categorize complex objects (in their case seashells) both haptically and visually. They found that visual and haptic object categorizations were similar, with the same shells being grouped together across both modalities. Additionally, object shape was an important factor for both visual and haptic categorization. This suggests that the same objects are typically represented together (rated as similar) independent of the modality in which they were encountered. However, if these representations are similar, there should be evidence of similarities in identification patterns across modalities.

Similarities between sight and touch are not limited to object categorization and similarity rating, but also apply to object identification. Using an object identification task in which participants were required to learn to recognize eight novel objects that differed along three dimensions (thick or thin, curved or straight, and round or tapered), Desmarais et al. (2017) found that object curvature was the primary source of identification error, independent of modality. Moreover, identification error patterns were similar between touch and sight, with participants generally confusing the same objects across both modalities, further highlighting that haptic and visual perception follow similar principles.

Common Underlying Neurological Processes

Beyond similarities in visual and haptic processing, there is overlap in the brain regions recruited by both modalities during object identification. Malach et al. (1995) found that, regardless of whether objects were seen or touched, completing an object identification task led to increased activation of the lateral occipital cortex, a structure associated with vision that also operates extensively for touch. Interestingly, Zangadze et al. (1999) further examined this overlap by inhibiting a region recruited during haptic and visual perception. Using transcranial magnetic stimulation (TMS), the authors inhibited activity in the occipital cortex of participants during a tactile orientation discrimination task. Participants placed the pad of their index finger on steel grating and were asked whether the grating was oriented parallel or perpendicular to their finger. Results showed that inhibiting the occipital cortex via TMS subsequently led to poorer discrimination accuracy. Therefore, these overlapping regions are not only recruited for perceiving shape and texture, but also object orientation.

Additionally, the activation of these regions is critical for their corresponding sensory process to occur (Zangadze et al., 1999). Using fMRI, James et al. (2002) also evaluated the degree of overlap between sight and touch using three-dimensional objects. Participants were assigned to either a visual or haptic condition in which they would explore a set of three-dimensional clay objects by sight or touch (James et al., 2002). After, they were placed in an fMRI. During scanning, participants viewed and/or touched visually and haptically primed objects, as well as a set of non-primed objects. Participants were not required to indicate whether objects had been explored previously. Results indicated that haptic exploration of the three-dimensional objects lead to increased neural activity in both the somatosensory cortex, as well as the medial and temporal occipital cortex, which are associated with visual processing (James et al., 2002).

The similarities between visual and haptic processing combined with the physiological evidence for the convergence of haptic and visual perception further demonstrates common underlying neurological processes. However, the two sensory modalities, while comparable, are not identical. Each mode of perception offers its own respective advantages and limitations.

Haptic perception

Though vision and touch are comparable, they are also distinct modalities of perception. Perhaps the most distinct contrast between visual and haptic perception is the manner in which they occur. Unlike visual identification, which naturally occurs in a collective manner such that an entire object can be viewed at once, haptic identification is performed serially (Lederman & Klatzky, 1987). For example, when reaching for a Christmas ornament, you may first perceive its glittered rough surface, followed by its thin edges before you identify the object as an ornament in the shape of a star. When exploring and identifying objects exclusively by touch, we often focus our attention toward features like contour and compliance, as these characteristics offer some of the most salient information that can be obtained by touch (Lederman & Klatzky, 1987). In fact, past research has found that for haptic exploration to be effective in any capacity, it may be necessary for an object's pliability, roughness, sharpness, and size to be accounted for, potentially explaining why the haptic identification of two-dimensional targets has been found to be less accurate (Krantz, 1972).

As one would expect, texture is also very important for touch. This is not only due to the fact that this modality is well-adapted for the detection of fine textural differences, but also because texture largely impacts one’s haptic perception above other features. Reales and Ballesteros (1999) analyzed implicit and explicit memory for haptic object perception by having participants complete an object identification task while wearing gloves, diminishing their sensitivity to texture while preserving shape perception. Participants attempted to identify both manufactured items (e.g., scissors) as well as natural objects (e.g., an onion). Additionally, some objects were preemptively primed, while others remained novel prior to testing. The researchers found that when participants were required to wear gloves that reduced their perception of texture but not shape, reaction times increased for both unstudied objects as well as objects that had even been previously studied, suggesting that texture is more important to object identification compared to shape for haptic identification.

Moreover, one’s haptic exploratory procedures will differ in response to the information that can be ascertained by an object’s features. For example, edge following may be an optimal strategy for exploring tapered objects like the edges of a particular Christmas ornament, while rubbing an object, such as the ornament’s glitter covered surface, may inform us about its texture (Lederman & Klatzky, 1987). In contrast to vision, haptic exploration and identification are generally conducted using multiple exploratory procedures simultaneously to ascertain as much information about the object as efficiently as possible (Lederman & Klatzky, 1987). So, if touch and sight are so different from one another in the manner in which they occur, how do they remain comparable? Why do they share similar identification accuracy rates, both rely on shape, and activate overlapping brain structures? The answer may lie in that both modalities input information into a shared mental representation.

Cross Modal Memory Representations

Some of the best evidence for shared representations is our ability to explore objects in one modality, and later recognize them in another. In their analysis into the transfer of memory for three dimensional objects, Easton et al. (1997) reported near equal performance between within-modality and cross-modal object recognition. In their study, participants were required to memorize the names of objects; half of the objects were encoded visually while the other half were encoded haptically. Additionally, between learning and testing, participants completed a verbal distractor task. During testing, additional objects were incorporated to serve as distractor stimuli. Participants assigned to a perceptual identification condition identified the objects by name as quickly and accurately as possible, while those assigned to the recognition condition indicated whether it had been previously presented. Across both tasks, Easton et al. (1997) found that cross-modal and within-modality performance were equally accurate, further validating that there exists a common representation of objects in memory that is accessible to both sight and touch (Easton et al., 1997).

Norman et al. (2004) also evaluated cross-modal performance in a "same/different" task using natural objects (e.g., 3-D printed bell peppers). Participants were presented with two natural objects in sequential order; some participants were assigned to a within-modality condition (haptic-haptic or visual-visual) while others completed the task cross-modally (haptic-visual or visual-haptic). For each trial, participants indicated whether the objects were the same or different. In addition to accurately recognizing the objects using the same modality, Norman et al. (2004) found that participants were able to explore natural objects in one modality and later recognize them in the other modality well above chance level, thereby offering further support for the comparability of cross-modal and within-modality recognition. These findings are consistent with more recent investigations into this phenomenon, which have reported cross-modal identification accuracy rates ranging from approximately 60-80% for naturally shaped objects such bell peppers and sweet potatoes (Norman et al., 2019).

The efficacy of cross-modal recognition also appears to be present from a young age. Even in early childhood, we are able to explore objects visually and later recognize them by touch. Bushnell and Baxt (1999) found that children as young as 5 years old could discriminate between target and distractor stimuli across modalities. The children were presented with objects that varied in familiarity; familiar objects included toys, articles of clothing, and food while novel stimuli consisted of tools and machine parts. After learning to recognize the objects by either sight or touch, the children were tasked with differentiating between previously presented stimuli and unexplored distractors. Though within-modality performance was more accurate, cross-modal discrimination was observed independent of object familiarity (Bushnell & Baxt, 1999). This suggests that, although comparable, within-modality identification is generally more accurate compared to cross-modal identification.

Encoding Specificity

Although cross-modal and within-modality identification are both highly accurate, we can generally expect individuals to demonstrate superior identification accuracy when they are tested in the same modality used during encoding. Encoding specificity is the phenomenon by which we are better able to retrieve memories if the conditions or context in which we are retrieving them resemble the conditions in which they were encoded (Tulving & Thomson, 1973). This applies to both physical (e.g., location) and psychological (e.g., mood) contexts. One potential cause for this is that the context in which memories are formed may offer retrieval cues that later assist in the retrieval of episodic memories (Tulving & Thomson, 1973).

Encoding specificity also applies to object identification. Norman et al. (2004) evaluated participants' performance on a same-different task using natural objects wherein participants indicated whether two simultaneously presented objects possessed the same shape. The objects were presented either unimodally or cross-modally. Norman et al. (2004) found that both unimodal and cross-modal identification performance was accurate, however participants assigned to the unimodal visual condition (vision-vision) performed better compared to those in the cross-modal condition (vision-haptic). This suggests that while vision and touch likely have an overlapping representation memory, visual information is still more accessible to sight compared to touch, aligning with encoding specificity.

Desmarais et al. (2017) investigated visuo-haptic object processing using a set of novel objects and also found evidence for encoding specificity. Participants completed an object identification task consisting of learning trials, in which they either visually, haptically, or bimodally explored a set of objects while being told each object's name, followed by test trials where participants identified each object by its corresponding nonword name, once by sight and once by touch. Similar to Norman et al. (2004), they found evidence for encoding specificity for visual learning: participants who first learned to recognize the objects by sight were more accurate in their identification performance when testing was also visual. Contrarily, when participants learned to recognize objects by touch, visual and haptic identification accuracy was equal (Desmarais et al., 2017). These findings suggest that haptic encoding may facilitate unique memory representations that are equally accessible to touch and sight.

Desmarais et al. (2021) conducted another study incorporating a similar object identification task, where they examined whether objects that are explored by touch are visualized, creating a multisensory memory trace equally accessible to both vision and touch. Participants were presented with either verbal or non-verbal characters during encoding and were later asked to recognize those characters among distracters. Consistent with their previous findings (Desmarais et al., 2017), Desmarais et al. (2021) observed a violation of encoding specificity for haptic learning: those who learned to recognize the objects by touch performed just as accurately during visual identification and haptic identification, independent of the distractor condition. Furthermore, only the verbal distractor interfered with identification accuracy independent of learning modality, suggesting that the formation of object representations in memory may rely on a verbal component (Desmarais et al., 2021). It should be noted, however, that the naming task employed by Desmarais et al. (2017; 2021) may have biased participants toward using verbal strategies. In light of this, the question remains, what is this shared memory trace between sight and touch composed of that facilitates this violation of encoding specificity for haptic learning?

Memory Representations: Evidence for an Amodal Component

According to amodal theorists, information obtained from separate sensory systems (i.e., touch and sight from fingers and eyes respectively) is not restricted to those modalities, but is instead transformed into an amodal symbolic representation that is accessible independent of the modality from which it was obtained (Kiefer & Pulvermuller, 2012). Therefore, according to amodal theories of perception, the information obtained from haptic exploratory procedures, such as edge-following, should be equally accessible to our visual and haptic perceptual systems. Such an amodal representation may help to explain the reported efficacy of cross-modal recognition, however this model cannot explain why the recently observed violation in encoding specificity is restricted to learning by touch (Desmarais 2017; 2021).

Interestingly, object shape has consistently been reported as the most dominant sensory quality in object categorization and recognition (Desmarais et al., 2017; Cooke et al., 2007). When people learn to recognize objects by touch, they may create an amodal representation based on object shape that is equally accessible to one's haptic and visual systems. This may help to explain why haptic learning led to equal performance for both haptic and visual identification in the studies conducted by Desmarais et al. (2017; 2021). However, this cannot explain why visual identification still benefits from visual learning (Desmarais et al., 2017; 2021). If an amodal component were equally accessible between the two modalities, cross-modal identification accuracy should be equal to that of within-modality identification. Therefore, an amodal component cannot be the only component of this memory trace shared by both touch and sight. In contrast to amodal theories, modality-specific theories of perception assume that conceptual representations are dependent and inseparable from their corresponding sensory systems. So, despite that visual information of an object's features can be shared with haptic systems, it is still more accessible to vision.

Memory Representations: Evidence for a Visual Component

Another possible component of the shared memory trace between sight and touch, which could facilitate a violation of encoding specificity for haptic learning, is a visual component: regardless of whether we touch or see an object, we may create a visual representation of it in memory, allowing us to "see" the object. Lacey and Campbell (2006) found that non-verbal visual distractors impacted cross-modal identification accuracy for unfamiliar objects, perhaps because participants were unable to visualize the objects. From these results, Lacey and Campbell proposed that memory representations for unfamiliar objects are likely visual. Interestingly, this proposal broadly aligns with the findings of Zangadze et al. (1999), who found that performance on a tactile discrimination task was worse when occipital structures involved in vision were inhibited via TMS. Together, these findings suggest that when one is unable to visualize what they touch, (through either visual interference or inhibition of the visual regions of the brain), they are less accurate in recognizing it.

Despite the strong evidence suggesting that memory representations are visual in composition, Desmarais et al. (2021) found that visual distractors (non-verbal ideographs) did not impact object identification accuracy. Contrarily, Desmarais et al. (2021) found that verbal distractors (letters of the English alphabet) interfered with identification accuracy regardless of learning modality and did not impact the observed violation in encoding specificity. This suggests that memory representations are also dependent on a verbal component.

Memory Representations: Evidence for a Verbal Component

We often use words to describe the features that an object possesses. For instance, one might feel a Christmas ornament and verbally describe it as round, stiff, and smooth. This phenomenon was demonstrated by Johnson et al. (1989), who conducted a study on the respective impacts of verbal and visualization strategies on a tactile to visual cross-modal object identification task. Children were assigned to one of three conditions prior to completing an object identification task with simple shapes. Those assigned to the verbal condition were instructed to assign names to the objects as they grasped them. Alternatively, those assigned to the imagery condition were instructed to create a mental image of each object corresponding to its overall shape. Participants in the control condition were not provided instruction on how to encode the objects in memory. Results indicated that when participants were instructed to use a particular strategy (naming or imagery), their identification accuracy depended on their corresponding verbal and visuospatial ability, respectively (Johnson et al., 1989). Furthermore, participants assigned to the control condition for which no instruction was provided tended to rely more on a naming strategy similar to those assigned to the verbal condition. This indicates that memory representations for objects may rely on verbal mechanisms and that these verbal mechanisms may be even more optimal for object identification compared to visualization.

Verbal descriptions may help us to encode the features that an object possesses. For example, it may be easier to encode the shape of a Christmas ball ornament into memory if one verbally describes it as round. Consequently, when presented with verbal distractors/interference, our identification accuracy may be worse as it becomes more difficult to verbalize these features. Lacey and Campbell (2006) investigated cross-modal memory representations for familiar and unfamiliar objects by having participants complete an object identification task while experiencing visual, haptic, or verbal interference. They found that for familiar objects (e.g., household items), no single type of interference greatly impacted identification accuracy, implying that memory representations for familiar objects rely on several mechanisms. Restricting one mechanism (e.g., verbal through verbal interference) likely leads participants to rely more on alternative mechanisms (e.g., visual and haptic). However, for unfamiliar objects (e.g., cave diving equipment), identification accuracy was worse when participants experienced verbal interference. This indicates that verbal mechanisms are important for encoding unfamiliar objects. While we may not directly name the objects, we can verbally describe their features during encoding (e.g., “this feels round, stiff, and smooth”).

Desmarais et al. (2021), who also found that verbal interference led to worse performance on an object identification task, suggest that the types of objects used in such a task may prompt individuals to rely on verbal strategies. It is possible that simple objects, such as those used by Desmarais et al. (2017; 2021) are easy to describe verbally (e.g., “this is round, this is straight, this is curved”), leading participants to rely more on verbal strategies than they otherwise would. Were the objects more difficult to verbalize, participants may be less prompted to rely on verbal strategies. In order to evaluate whether object complexity impacted the types of information used to form object representations, the current study used both simple objects (blobs) as well as complex objects (widgets).

Together, these results suggest that verbal mechanisms are "bound" to sight and touch, facilitating visual and haptic encoding for novel objects. Lacey and Campbell (2006) note that both verbal and visual interference disrupted encoding of unfamiliar objects, highlighting that for sight, verbal mechanisms may mediate our formation of object representations in memory. Meanwhile for touch, verbal interference disrupted identification accuracy independent of object familiarity, implying that haptic representations in memory may actually rely on verbal mechanisms (Lacey & Campbell, 2006). Regardless of the extent to which verbal mechanisms assist in forming object representations in memory, they appear to be "bound" to both visual and haptic encoding of novel objects.

Santana and Galera (2014) investigated the binding of visuospatial and verbal-spatial memory representations in a serial recognition task. Participants were presented with visual stimuli consisting of four letters organized into the shape of a diamond. Stimuli could be defined as either visually relevant (the font of the letters was relevant), verbally relevant (the identity of the letters was relevant), or spatially relevant (the organization of the letters into a diamond pattern was relevant). Following this, they were presented with four new stimuli that varied along visual (different fonts), verbal (different letters), and spatial (different letter organization: one letter was moved to a new location) dimensions. Participants were asked to indicate whether an alteration had been made to the relevant dimension, while ignoring alterations to the other two dimensions. For example, if only the verbal dimension was relevant, participants were required to indicate when changes were made to letter identity, while ignoring alterations made to the organization or font of the letters. Some participants were also required to read aloud the numbers 1 to 5 prior to testing, which functioned as verbal interference. Santana and Galera found that when participants were asked to attend to the spatial dimension, participants would frequently respond that a change in letter organization had occurred when only the font and/or letter identity had been altered. However, the opposite was not true. When font and letter identity were relevant, alterations to letter organization generally did not impact the response. Interestingly, when participants were exposed to verbal interference prior to test, changing the letter organization decreased accuracy when the visual dimension of the stimuli was relevant, suggesting that verbal interference facilitated binding of visual and spatial information. These findings further indicate that verbal mechanisms are bound to visual encoding of stimuli. However, it may be possible that these patterns depend on the individual.

While amodal, visual, and verbal theories offer insight into the types of information used to create object representations in memory, one common limitation of these theories is that they fail to account for unique differences between individuals. For instance, does everyone verbalize or visualize objects to the same extent? Is it possible that individuals vary on their ability to process different types of information, thereby impacting the types of information used to create object representations in memory?

Memory Representations: The Impact of Cognitive Style

Cognitive styles, not to be confused with learning styles (Pashler et al., 2008), are described as one's most effective and preferred method for obtaining, manipulating, and applying information (Blazhenkova & Kozhevnikov, 2009). There are currently three validated cognitive styles: object imagers, spatial imagers, and verbalizers. Object imagers are adept at visualizing clear, colourful, static images or scenes (Blazhenkova & Kozhevnikov, 2009). If asked to imagine a fruit, an object imager would likely be capable of visualizing a high-resolution image of a vibrant red apple. Alternatively, spatial-imagers tend to visualize objects through schematic representations, building the object from the ground up as opposed to viewing it as a pictorial whole. Spatial-imagers rely on spatial relationships and excel at manipulating and orientating an object in space (Blazhenkova & Kozhevnikov, 2009). Finally, verbalizers do not tend to visualize objects, but instead rely on verbal descriptions of an object's features (Blazhenkova & Kozhevnikov et al., 2009). The Object-Spatial-Imager-Verbalizer-Questionnaire, developed and validated by Blazhenkova & Kozhevnikov (2009) can be used to measure the degree to which individuals score along each of these three subscales.

Cognitive style can impact performance on different cognitive or perceptual tasks, with certain cognitive styles yielding improved or worsened performance depending on the nature of the task. Tascón et al. (2017) found that participants who scored higher on the field independence test (FIT), which reflects higher levels of a spatial cognitive style, performed better on a spatial memory task. Participants were first required to memorize the location of a green box in a virtual image. Afterwards, they were presented with ten new images and were asked whether the green box was in the same initial position. Tascón et al. (2017) found that participants who scored higher on the field independence test were more accurate on the spatial memory task, likely indicating that those who possess a spatial cognitive style are most sensitive to small changes in spatial relationships.

For some cognitive and perceptual tasks, different cognitive styles benefit different aspects of the same task. Pazzaglia and Moè (2013) found that spatial-imagers, particularly those proficient at mental rotation, were better able to learn and memorize two-dimensional maps that consisted of rich visual features compared to verbalizers. Conversely, verbalizers were more proficient at memorizing a 2D map that consisted of verbal labels. Furthermore, Marks (1973) investigated whether increased levels of self-reported vividness of mental imagery (comparable to the object-imager cognitive style) related to improved recall of images. Participants were presented with a series of photographs and were asked to memorize them. The photographs consisted of images ranging from objects (e.g., a golf ball) to scenes (e.g., a lighthouse surrounded by clouds). After, participants were asked to recall subtle details found throughout the photos. For example, "what was the number written on the golf ball". Participants who reported higher levels of vivid mental imagery demonstrated higher accuracy rates of picture recognition, further highlighting the impact of cognitive style on one's performance along cognitive and perceptual tasks.

The benefit of a verbal cognitive style has also been investigated as it pertains to visuospatial descriptions. Meneghetti et al. (2014) investigated the mediating role of cognitive styles on recall of visuospatial descriptions by asking participants to complete both self-report measures of cognitive style (including the OSIVQ), as well as objective measures of verbal comprehension. Participants read a written passage that provided a detailed visuospatial description of a path through a park, which incorporated different landmarks including a waterfall, boulevard, bridge, and pond, as well as two turns. Upon completion of the study, scores along the verbal scale were positively correlated with accuracy on recall of the visuospatial passage (.21), however it is interesting to note that sores on the object-imager scale were more strongly correlated with recall accuracy (.30). These results indicate that an imagery-bound cognitive style may be more effective for tasks involving visualization, even when the task is verbal in design.

Summary and Current Study

Overall, it remains unclear what types of information people use to create object representations in memory. Theories examining a more global “one size fits all” approach to object representations seem to point toward a verbal component, with verbal interference being found to reduce object identification accuracy (Lacey & Campbell, 2006; Desmarais et al., 2017; 2021). This suggests that when we are less able to rely on verbal mechanisms, there would be a corresponding decline in our ability to form object representations in memory. Moreover, it appears that people tend to automatically rely on verbal strategies, such as naming, over alternative strategies like visualization when performing object identification tasks (Johnson et al., 1989). Together, these findings suggest that object representations in memory are at least partially comprised of a verbal component. However, the extent to which this is true may depend on the individual and more specifically, the cognitive style they possess.

To examine this, we asked participants to complete the OSIVQ, which provided a measured of cognitive style along each dimension (object, spatial, verbal). Following this, participants completed series of learning and test trials in order to learn to identify the names of eight novel objects. During the eight learning trials, participants either touched or saw each object and were told its nonword name. Next, participants identified each object twice, once by sight and once by touch. Recall that the verbal interference observed by Desmarais et al. (2021) was potentially attributable to the types of objects used. It is possible that simple objects are easy to describe verbally, leading participants to rely more on verbal strategies than they otherwise would. Therefore, in the present study some participants learned to recognize a set of simple objects (blobs), while others learned to recognize complex objects (widgets). Furthermore, some participants were assigned to a control group and completed the identification task on its own. The remaining participants were assigned to one of the two interference conditions, completing the identification task while concurrently executing either a verbal or visuospatial distractor task. This resulted in a 2 (learning condition: haptic or visual) × 2 (identification modality: haptic or visual) × 3 (distractor condition: control, verbal interference, or visual-spatial interference) × 2 (object type: simple or complex) mixed-design, for which the within-subject factor was identification modality, while learning condition, object type, and distractor condition served as the between-subjects factors.

Several hypothesises were made. First, that participants learning to recognize complex objects will require more blocks to reach criterion while also producing more identification errors compared to those learning simple objects. Second, that participants assigned to a distractor condition will require more blocks to reach criterion and produce more identification errors compared to those in the control condition. Third, that there will be an interaction between object type and interference condition. Participants learning to recognize complex objects will produce more identification errors and require more blocks to reach criterion if they are assigned to the visual-spatial distractor condition compared to the verbal distractor condition, as I expect representations for complex objects to be visual due to how difficult they are to verbalize. Alternatively, participants learning to recognize simple objects will produce more identification errors and require more blocks to reach criterion if they are assigned to the verbal distractor compared to the visual-spatial distractor, as I expect representations for simple objects to be verbal due to how easily their features can be verbalized (Desmarais et al., 2021). Fourth, that distractor tasks will impact participants differently according to their cognitive style. Participants assigned to the verbal distractor condition will experience greater interference if they score highly as verbalizers on the OSIVQ. Therefore, I expect that there will be a positive correlation between identification errors and verbalizer scores in the verbal interference condition. Contrarily, participants assigned to the visual-spatial distractor condition will experience greater interference if they score highly as object or spatial-imagers on the OSIVQ. Therefore, I expect that there will be a positive correlation between identification errors and object/spatial-imager scores in the visual-spatial interference condition.

Method

Participants

One hundred fifty-five participants (106 females, 34 males, six who identified as other, and nine who declined to respond) enrolled in undergraduate courses at Mount Allison University were recruited for this study. Participants had a mean age of 19 (*SD* = 3.40 years). Eleven participants did not indicate their age. Participants reported normal or corrected-to-normal vision along with a normal sense of touch. Most participants (131) reported being right-handed (13 were left-handed and eleven declined to respond). Individuals were compensated $6.00 for each half-hour of participation or, if they preferred, received 0.5 credits per half-hour of participation to be counted toward their Introduction to Psychology course.

Materials

We used the Object-Spatial Imagery and Verbal Questionnaire to assess participants' preferences and experiences along three distinct cognitive styles: object imagery, spatial imagery, and verbal dimensions (OSIVQ; Blazhenkova & Kozhevnikov, 2009). The OSIVQ is a self-report questionnaire that consists of 45 items spread evenly across 3 scales, with each scale assessing one of the three cognitive styles. Participants are asked to indicate their level of agreement with each statement (e.g., "When I imagine the face of a friend, I have a perfectly clear and bright image") on a scale from 1 (total disagreement) to 5 (total agreement). Upon completion, scores are summed with a possible range of 15 to 75 per scale, with higher scores indicating greater preference for each scale's corresponding cognitive style.

Participants learned to recognize one of two sets of eight psychophysically scaled novel objects (Desmarais et a., 2007) composed of grey PVC. Simple objects (blobs) were approximately 81mm in length and were smooth and hard to the touch. Simple objects varied in terms of thickness, tapering, and curvature; these objects were either thick or thin, round or tapered, and straight or curved. Each simple object was comprised of a combination of these features (see Figure 1A). Alternatively, the complex object set consisted of eight multi-feature objects (widgets) composed of grey LEGO blocks. Each complex object was approximately 70mm in length. Objects varied along three features: a smooth or grooved top, as well as the presence/absence of upward and/or downward wings. Each complex object was comprised of a combination of these features see Figure 1B).

We used a set of eight non-words to identify the objects: “YOOT”, “BAIV”, “FINT”, “MALG”, “VERP”, “GROV”, “HONG”, and “JORL”. The names were presented verbally.

We presented the objects to participants through one of two unique, two-story presentation boxes. Each box was placed behind a clear layer of plexiglass, against a small occluded opening that was cut toward the bottom to allow participants to reach into the box. This allowed participants to explore the objects haptically by reaching into the opening while also preventing them from seeing the objects. Objects that were to be explored visually, but not haptically, were placed on the top surface of the presentation box, while objects to be explored haptically were placed on the bottom surface of the box. The presentation box designed for the multi-feature objects (see Figure 2A) consisted of two circular LEGO platforms upon which objects were displayed.

Meanwhile, the presentation box designed to display simple shape objects (see Figure 2B) possessed styrofoam blocks, which were attached to the top surface of the box, as well as inside the haptic observation chamber. The blocks possessed a hole approximately 1cm in diameter, which the simple objects were attached to via a metal dowel of approximately the same diameter.

We used two types of distractors: visuospatial distractors and verbal distractors. To create a visuospatial distractor, we used a third box that contained four 2” x 2” wooden blocks placed inside (see Figure 3). The four blocks were positioned in two evenly spaced rows and were not visible to participants. The verbal distractor consisted of letters taken from all 26 letters of the English alphabet. During learning trials, letters were presented in sets of four with each quadruplet being randomized between participants.

Figure 1. Images of objects used. A) Simple shape set. B) Multi-feature shape set.

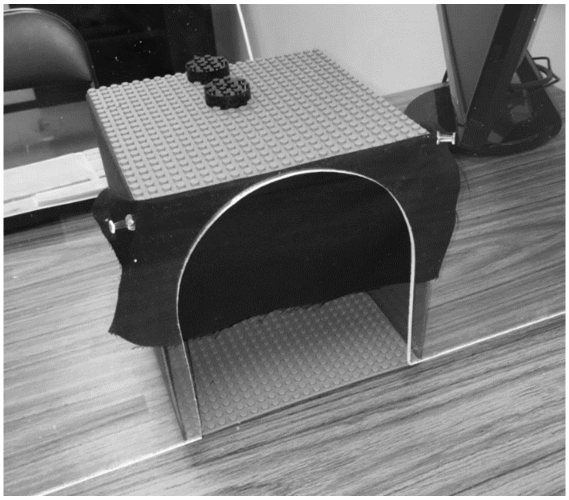


Figure 2A. Presentation box for multi-feature objects.

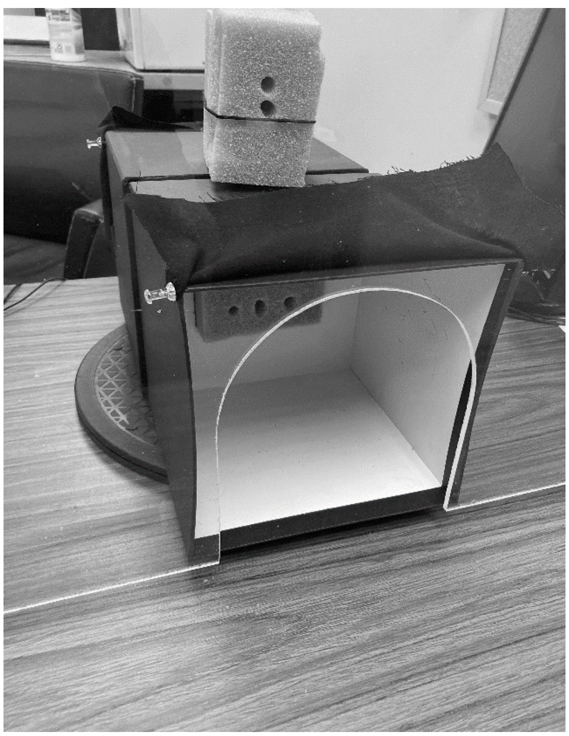


Figure 2B. Presentation box for simple shape objects.

Figure 3. Visuospatial distractor box.

Procedure

Participants first completed the OSIVQ before completing a series of learning and test trials in order to learn to recognize one set of eight novel objects. Half of the participants completed blocks with the simple object set while the other half learned to recognize complex objects. Approximately one-third of participants were assigned to a control group and completed the recognition task on its own. The remaining participants were equally assigned to one of the two interference conditions, completing the same recognition task while concurrently executing either a verbal or visuospatial distractor task.

Learning Trials

During learning trials, objects were presented randomly one at a time along with their nonword name. Participants were seated at arm's length away from the presentation box with their eyes closed. Ninety-six of the participants explored objects visually, while the other 59 explored objects haptically. For visual exploration, participants awaited the cue "this is (name of object)," which would signal them to open their eyes. They would then have 2 seconds to look at the mounted object before the cue "close" would indicate for them to close their eyes. Each shape was presented once in random order for a total of eight leaning trials. The procedure for haptic exploration was identical with the exception that participants were required to reach for and grasp the objects upon hearing the auditory cue. After 5 seconds, the cue "remove" signaled participants to discontinue haptic exploration and remove their hand from the apparatus. Haptic exploration lasted 5 seconds, as opposed to 2 seconds, in order to allow for natural sequential hand exploration.

Verbal Distractor Condition

The procedure for the verbal distractor condition was identical to that of the control with the exception of the presentation of a quadruplet of randomized letters prior to the eight learning trials. Following the eight learning trials, participants were asked to repeat which four letters they had previously been presented. Accuracy was recorded.

Visuospatial Distractor Condition

The procedure for the visuospatial distractor condition was identical to that of the control condition with the exception of a visuospatial distractor shown to interfere with visualization (Poirier et al., 2019). At the beginning of each learning trial, participants tapped each of the four squares of the distract box at a rate of 2 taps per second in a counterclockwise motion. If participants stopped tapping, the experimenter asked them to resume tapping and recorded the occurrence.

Test Trials

Once participants completed a block of eight learning trials, they then completed 16 test trials, during which participants identified each object once visually and once haptically in random order. Participants sat at arm's length away from the presentation box with their eyes closed. For visual identification trials, the cue "open" signaled participants to open their eyes and identify the object, while the cue "close" signaled to the participant to close their eyes once again while the researcher replaced the shape. For haptic identification trials, the cue "reach" signaled for participants to reach with their dominant hand to identify the object, while "remove" once again instructed participants to remove their hand from the presentation box. Throughout test trials, participants were permitted to see/touch each object until they produced a response. In order to ensure that participant's errors were attributable to confusion between objects as opposed to merely forgetting the nonword names, a sheet of paper with all eight nonword names was available for participants' viewing throughout the test trials. Moreover, a new sheet containing a different order of these nonword names was provided for each test block. After completing 16 test trials, participants completed eight more learning trials followed by 16 more test trials. This sequence of learning and test trials continued until participants were capable of correctly identifying all eight novel objects in both modalities for two consecutive testing blocks, which took approximately two hours.

Results

Fourteen participants were excluded from the analysis because they still produced identification errors after 150 minutes of testing, reducing the final sample to 141 participants. Six of these excluded participants were in the haptic learning condition, where four learned to recognize blobs (two who completed the procedure under control conditions, one who experienced a verbal distractor, and one who also experienced a visuospatial distractor) while two participants learned to recognize widgets (one who completed the procedure under control conditions, and one who experienced a verbal distractor). The remaining eight excluded participants were in the visual learning condition, where four learned to recognize blobs (two who experienced a verbal distractor, and two who experienced a visuospatial distractor) while four learned to recognize widgets (three under control conditions, and one who experienced a verbal distractor).

Blocks to Criterion

The number of blocks participants required to reach criterion were analyzed in a 2 (learning condition: haptic or visual) × 2 (identification modality: haptic or visual) × 3 (distractor condition: control, verbal interference, or visuospatial interference) × 2 (object type: simple or complex) Bayesian repeated measures ANOVA, for which the within-subject factor was identification modality, while learning condition, object type, and distractor condition served as the between-subjects factors. The strongest model included main effects of identification modality, object type, learning condition, and distractor condition. This model also included interactions between object type and learning condition, as well as between object type and identification modality. The BF10 for this model was 4.6×10^4 suggesting that these data were 4.6×10^4 times more likely to occur under the model, providing strong evidence for the alternative hypothesis. Generally, participants required fewer blocks to reach criterion for visual identification (*Mean number of blocks* = 5.62) than to reach criterion for haptic identification (*Mean number of blocks* = 6.06*).* Participants who learned to recognize simple objects required fewer blocks to reach criterion (*Mean number of blocks* = 5.74) than participants who learned to recognize complex objects (*Mean number of blocks* = 5.94). Participants who learned to recognize objects by sight required fewer blocks to reach criterion (*Mean number of blocks* = 5.77) than participants who learned to recognize objects by touch (*Mean number of blocks* = 5.96). The main effect of distractor condition was examined with a pre-planned Bayesian paired samples t-test. Participants who completed the task under control conditions required a similar number of blocks (*Mean number of blocks* = 5.24) to reach criterion compared to those in the verbal distractor condition (*Mean* *number of blocks* = 5.96; BF01 = 1.85). Also, participants who completed the task within the verbal distractor condition required a similar number of blocks to reach criterion compared to those in the visuospatial distractor condition (*Mean number of blocks* = 6.39; BF01 = 7.26). However, participants who completed the task under control conditions required fewer blocks to reach criterion compared to those in the visuospatial distractor condition (BF10 = 6.84).

The interaction between object type and learning condition was analyzed using Bayesian paired samples t tests. Participants who learned to recognize simple objects by sight needed slightly fewer blocks to reach criterion (*Mean number of blocks* = 5.27) than participants who learned by touch (*Mean number of blocks* = 6.54; BF10 = 2.00), though this is anecdotal. However, participants who learned to recognize complex objects by sight required a similar number of blocks to reach criterion (*Mean number of blocks* = 6.27) compared to participants who learned by touch (*Mean number of blocks* = 5.41; BF01 = 1.88), though this is also anecdotal. The results are displayed in Figure 4.

The interaction between object type and identification modality was also analyzed using Bayesian paired samples t tests. Participants who learned to recognize simple objects needed fewer blocks to reach criterion for visual identification (*Mean number of blocks* = 5.29) than haptic identification (*Mean number of blocks* = 6.20; BF10 = 3978.36). However, participants who learned to recognize complex objects required a similar number of blocks to reach criterion for visual identification (*Mean number of blocks* = 5.96) and haptic identification (*Mean number of blocks* = 5.93; BF01 = 7.46). The results are displayed in Figure 5.

Figure 4

Mean Number of Blocks Needed to Reach Criterion for Participants Learning to Recognize Simple or Complex Objects by Sight or by Touch

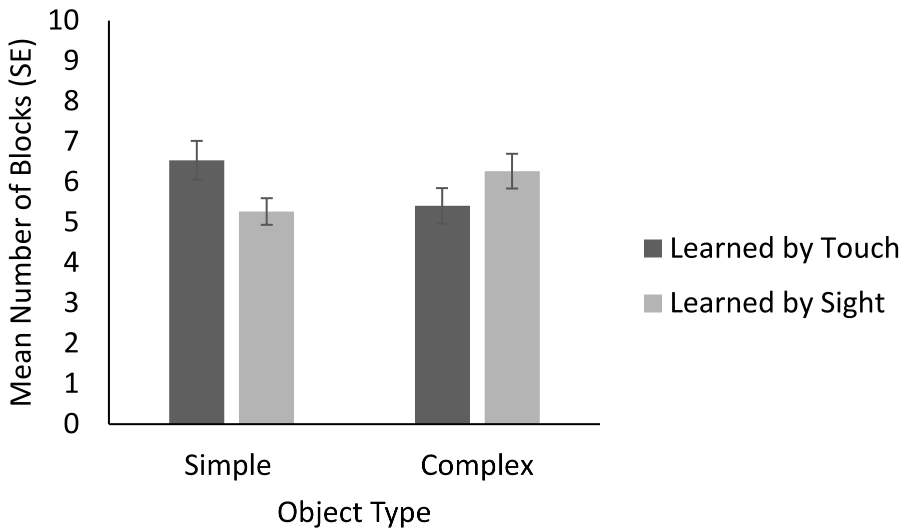
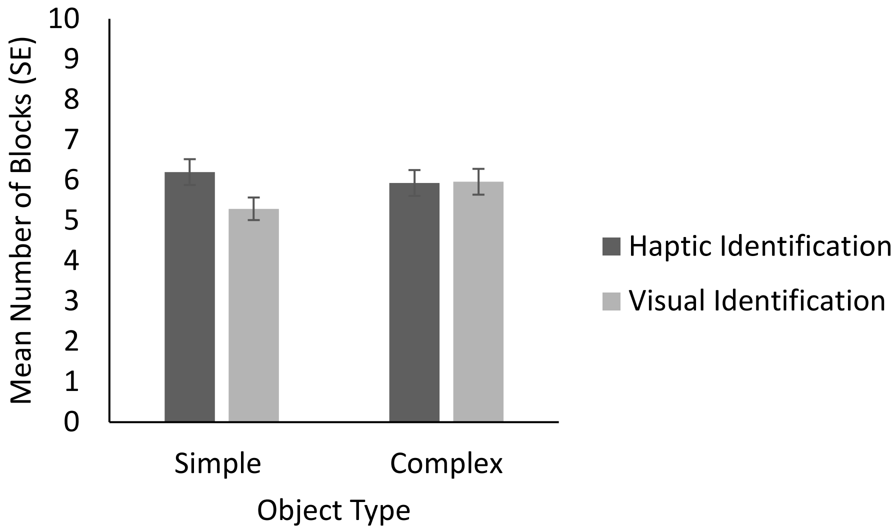


Figure 5

Mean Number of Blocks Needed to Reach Criterion for Participants Identifying Simple or Complex Objects by Sight or by Touch



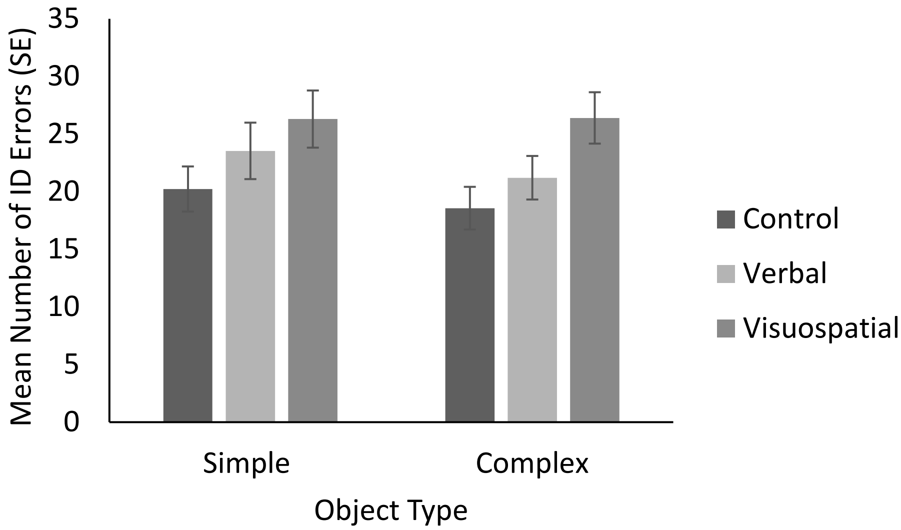
Total Number of Errors

Participants' total number of identification errors were analyzed in a 2 (learning condition: haptic or visual) × 2 (identification modality: haptic or visual) × 3 (distractor condition: control, verbal interference, or visuospatial interference) × 2 (object type: simple or complex) Bayesian repeated measures ANOVA, for which the within-subject factor was identification modality, while learning condition, object type, and distractor condition served as the between-subjects factors. The strongest model included main effects of identification modality, object type, learning condition, and distractor condition. This model also included interactions between object type and distractor condition, as well as between identification modality, object type, and learning condition. The BF10 for this model was 1.51×10^5 suggesting that the data were 1.51×10^5 times more likely to occur under the model, providing strong evidence for the alternative hypothesis. Generally, participants produced fewer errors when identifying objects by sight (*Mean number of errors* = 22.19) than by touch (*Mean number of errors* = 23.33). Participants who learned to recognize simple objects produced fewer errors (Mean number of errors = 23.31) than participants who learned to recognize complex objects (*Mean number of errors* = 22.22). Participants who learned to recognize objects by sight produced fewer errors (*Mean number of errors* = 21.90) than participants who learned to recognize objects by touch (*Mean number of errors* = 24.20). The main effect of distractor condition was examined with a pre-planned Bayesian paired samples t-test. Participants who completed the task under control conditions produced a similar number of identification errors (*Mean number of errors* = 19.43) compared to participants in the verbal distractor condition (*Mean number of errors* = 22.35; BF10 = 0.98). However, participants who completed the task under control conditions produced fewer identification errors compared to those in the visuospatial distractor condition (*Mean number of errors* = 26.73; BF10 = 1484.43). Additionally, participants in the verbal distractor condition produced fewer identification errors compared to those in the visuospatial distractor condition (BF10 = 2.69).

The interaction between object type and interference was analyzed using Bayesian independent samples t tests. Participants who learned to recognize simple objects under control conditions produced a similar number of identification errors (*Mean number of errors* = 20.23) compared to those in the verbal distractor condition (*Mean number of errors* = 23.54; BF01 = 1.32). Participants within the control conditions also produced a similar number of identification errors compared to those in the visuospatial distractor condition (*Mean number of errors* = 26.30; BF01 = 0.78). Participants within the verbal distractor condition also produced a similar number of errors compared to participants in the visuospatial distractor condition (BF01 = 2.65). For participants who learned to recognize complex objects, there was no difference in the mean number of identification errors for those in the control condition (*Mean number of errors* = 18.57) compared to participants in the verbal distractor condition (*Mean number of errors* = 21.21; BF01 = 2.29). Similarly, there was no difference in the mean number of errors for those in the verbal distractor condition compared to participants in the visuospatial distractor conditions (*Mean number of errors* = 26.40; BF01 = 0.99). However, participants who completed the task under control conditions produced fewer identification errors compared to those in the visuospatial distractor condition (BF10 = 4.62). The results are displayed in Figure 6.

Figure 6

Mean Number of Identification Errors Made by Participants Learning to Recognize Simple and Complex Objects Under Control or Interference Conditions



The interaction between identification modality, object type, and learning modality was analyzed by examining the performance of participants who learned to recognize either simple of complex objects using Bayesian paired samples t test. Participants who learned to recognize simple objects by sight produced a greater number of identification errors for haptic (*Mean number of errors* = 22.68) compared to visual (*Mean number of errors* = 18.80; BF10 = 57.10×10^4) identification. Contrarily, participants who learned to recognize simple objects by touch produced a similar number of identification errors for haptic (*Mean number of errors* = 27.69) and visual (*Mean number of errors* = 27.65; BF01 = 4.82) identification. Results are presented in Figure 7A. Participants who learned to recognize complex objects by touch produced a similar number of identification errors for haptic (*Mean number of errors* = 20.63) and visual (*Mean number of errors* = 21.07; BF01 = 3.67) identification. Similarly, participants who learned to recognize complex objects by sight produced a similar number of identification errors for haptic (*Mean number of errors* = 23.07) compared to visual (*Mean number of errors* = 23.05; BF01 = 6.12) identification. The results are displayed in Figure 7B.

Figure 7A

Mean Number of Identification Errors Made by Participants Learning and Identifying Simple Objects by Sight or by Touch

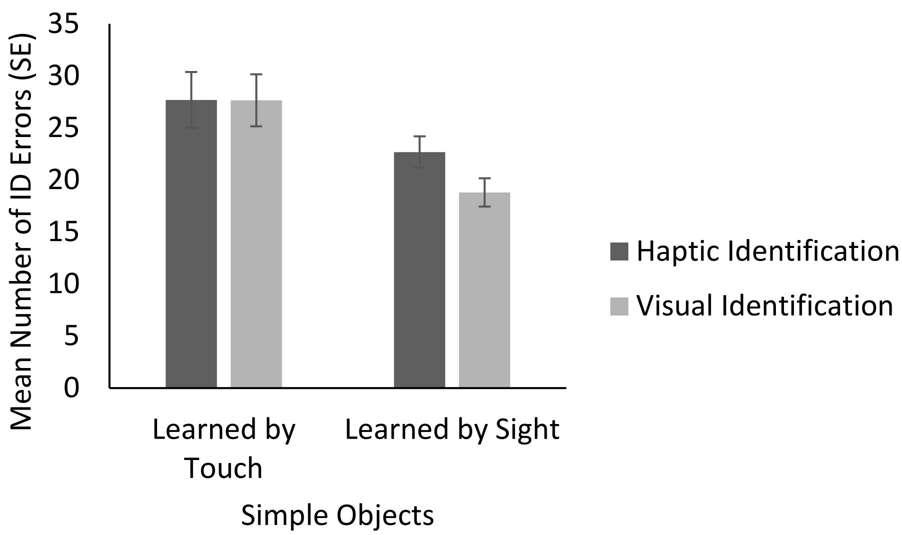
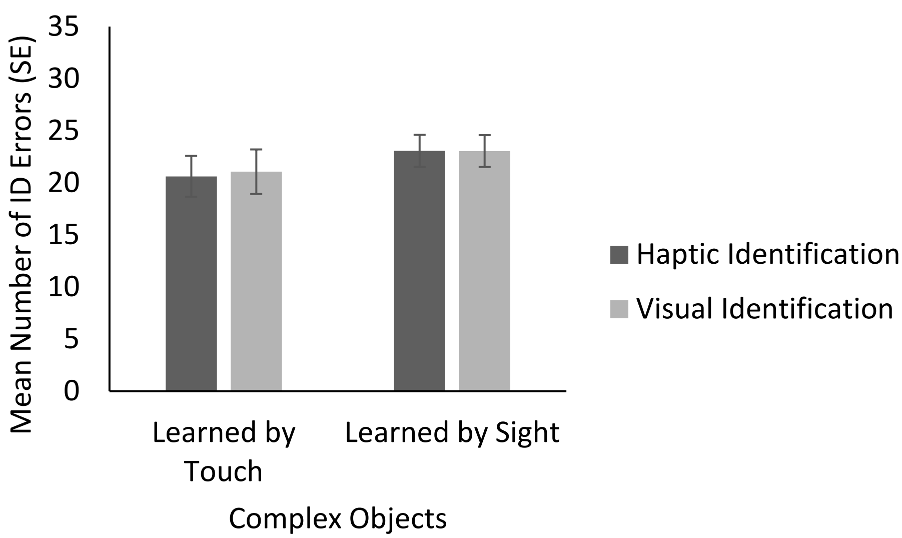


Figure 7B

Mean Number of Identification Errors Made by Participants Learning and Identifying Complex Objects by Sight or by Touch



Correlations

Initially, it was hypothesized that distractor tasks would impact participants differently according to their cognitive style. However, due to an insufficient number of participants within each distractor condition, it was not possible to include this analysis in the current study. Instead, we examined whether identification performance across both simple and complex objects learned by touch or by sight would be associated with scores along each subscale of the OSIVQ under control conditions. Bayesian Pearson correlations revealed negative relationships between scores along the OSIVQ spatial-imager subscale and blocks to reach criterion by touch, blocks to reach criterion by sight, total number of haptic identification errors, and total number of visual identification errors for complex objects learned by touch. No such correlations were observed for participants who learned to recognize simple objects. In other words, participants who learned to recognize complex objects by touch who also scored highly as spatial-imagers required fewer blocks to reach criterion and produced fewer identification errors across both identification modalities. For full correlations and BF10 values, please see Table 1.

Table 1

Correlations Between Identification Performance and OSIVQ Spatial-Imager Scores for Complex Objects Learned by Touch

Variable	OSIVQ Spatial-Imager Scores	
	r	BF10
Blocks Haptic	-.83	10.16
Blocks Visual	-.82	9.18
Total Errors Haptic	-.82	9.16
Total Errors Visual	-.83	10.92

Discussion

The current study examined the types of information used to create visuo-haptic object representations in memory, and whether this depends on individual differences in cognitive style. Results showed that participants who completed the task under control conditions displayed superior identification performance compared to participants assigned to the visuospatial condition, especially for those learning to recognize complex objects. Participants learning to recognize simple objects performed better when learning and identifying objects by sight compared to touch. Consistent with previous findings (Desmarais et al., 2017; 2021), we observed a violation of encoding specificity for participants who learned to recognise simple objects by touch, as they produced a similar number of errors across haptic and visual identification. A violation of encoding specificity was also observed for participants whole learned to recognize complex objects, regardless of learning modality. Identification performance was correlated with scores along the spatial-imager subscale of the OSIVQ for participants who learned to recognize complex objects by touch. However, there were no correlations between cognitive style and performance for participants who learned to recognize complex objects by sight, or for those who learned to recognize simple objects.

Participants who completed the task under control conditions produced fewer identification errors and required fewer blocks to reach criterion compared to those who completed the task with a visuospatial distractor. Intuitively, this finding is to be expected; as the mental workload of a task increases (i.e., encoding object features while simultaneous tapping in a counter-clockwise pattern), cognitive resources must be divided between tasks, decreasing performance across both (May & Elder, 2018). This degradation of performance is likely exacerbated when concurrent tasks directly interfere with one another. During learning trials, participants in the visuospatial distractor condition completed a block-tapping task shown to interfere with visuospatial coding (Poirier et al., 2019). Critically, visuospatial coding assists in the formation of multimodal representation in memory, allowing for the binding of visual features (e.g., object identity) with other sensory information, such as haptic perception (Groen et al., 2021). It is plausible that performance on an identification task that relies on visuo-haptic integration would therefore be degraded when one divides their attention toward a concurrent distractor task which directly interferes with the integration of visual and haptic perception.

Regarding the number of blocks participants required to reach criterion, it is interesting to note that the visuospatial distractor, but not the verbal distractor, negatively impacted performance. Moreover, participants in both the control condition as well as the verbal distractor condition produced fewer errors compared to those in the visuospatial distractor condition. This is surprising, given that verbal distractors have consistently been shown to interfere with identification performance (Lacey & Campbell, 2006; Desmarais et al., 2021). It is also relevant to note, however, that in our sample most participants (n = 107) were imagers (either object or spatial) while few (n = 32) were verbalizers, as measured by the OSIVQ. If an individual's most effective method for obtaining and applying information relies on visuospatial mechanisms (Blazhenkova & Kozhevnikov, 2009), experiencing a distractor task shown to interfere with visuospatial processing is likely to degrade performance on cognitive tasks (Poirier et al., 2019). It is unlikely that such individuals would be severely impacted by verbal interference, as they are less reliant on verbal mechanisms. This is not to suggest that imagers never use verbal mechanisms, verbal information may just be less salient in most cognitive tasks to these individuals (Blazhenkova & Kozhevnikov, 2009).

With this in mind, it is unsurprising that participants who learned to recognize complex objects under control and verbal distractor conditions, produced fewer errors compared to those who experienced a visuospatial distractor. As Desmarais et al. (2021) note, an object's features may prompt individuals to rely on different encoding strategies. Simple objects, such as those used by Desmarais et al. (2017; 2021) are easy to describe verbally (e.g., "this is round, this is straight, this is curved"), leading participants to rely more on verbal strategies, as they are more salient. However, the complex objects used within the current study, which vary along local features, are much harder to describe using words (e.g., " this is smooth and possesses no wings, this is jagged and possesses two upward wings and two downward wings"). As such, participants within the verbal distractor condition likely experienced little interference, as verbal mechanisms were already ineffective when learning to recognise complex objects. Therefore, memory representations for complex objects appear to be visuospatial in composition, rather than verbal.

It is curious to note that, contrary to what was hypothesized, identification performance for simple objects was similar for participants in the control condition compared to those who experienced a verbal distractor. If simple objects are easily verbalized (Desmarais et al., 2021), it is reasonable to expect a verbal distractor would interfere with performance. Indeed, using a similar protocol, Desmarais et al. (2021)

found that participants who experienced a verbal distractor required more blocks to reach criterion and produced more errors compared to controls. Once more, this may be explained by the fact that the majority of participants within the current study were imagers, suggesting that, regardless of how easy simple objects are to verbalize, most participants continued to rely on visuospatial information. Indeed, those who learned to recognize simple objects in the visuospatial distractor condition did produce more errors compared to controls, supporting this notion. While the difference in errors was not significant, this further highlights that individuals differ on the types of information they use to form object representations, and when they are less able to access or use that information, object identification performance is degraded.

It was also found that participants who learned to recognize simple objects by sight required fewer blocks to reach criterion compared to participants who learned to recognize simple objects by touch. Similarly, participants who identified simple objects by sight produced fewer errors compared to those who identified simple objects by touch. Consistent with past research on object identification (Desmarais et al., 2017; 2021), we also identified a violation of encoding specificity for participants who learned to recognise simple objects haptically. Participants who first learned to recognize simple objects by touch produced a similar number of errors independent of identification modality. Once more, these findings may be attributable to the salience of different perceptual information. Lakatos and Marks (1999) investigated the importance of global features when exploring objects by either sight or touch. They found that participants who explored objects by sight subsequently rated objects as more similar if they possessed similar global features. These findings parallel those of Cooke et al. (2007), who found that when participants rated objects by similarity using sight alone, global features such as shape were the most important factors. Together, these findings suggest that visual perception is more attuned for processing global, rather than local, features. Given that the simple objects used within the current study differ along global features (straight or curved, thick or thin, and tapered or rounded), it follows that simple objects were therefore more salient to vision compared to touch, leading to better identification performance when simple objects were learned or identified by sight. Even when participants first learned to recognize simple objects by touch, their global features therefore made visual identification just as accurate as haptic identification, producing a violation of encoding specificity.

The same violation of encoding specificity was also observed for complex objects learned haptically. Participants who first learned to recognize complex objects by touch produced a similar number of errors independent of identification modality. Unlike the simple object set, which possesses global features that are more accessible to vision (Lakatos & Marks, 1999), the complex object set differs along local features including edges and vertices. However, unlike sight, touch does not appear to be more attuned for processing either global or local object features. In the same study, Lakatos and Marks (1999) asked participants to explore and evaluate the similarity of objects by touch. Some participants completed the task under control conditions, while others simultaneously wore gloves designed to facilitate either global or local feature exploration. The researchers found that haptic object similarity ratings did not differ based on which types of features participants explored (global or local), suggesting that haptic perception is equally effective regardless of whether an object possesses global or local features. These findings, in conjunction with the violation of encoding specificity found for complex objects in the current study, suggest that haptic object exploration may facilitate a more complex memory representation, which is accessible to both sight and touch.

Finally, for participants who learned to recognize complex objects by touch, we observed a negative correlation between the number of blocks required to reach criterion as well as the number of errors produced, with scores along the spatial-imager subscale of the OSIVQ. In other words, when learning to recognize complex objects haptically, spatial-imagers demonstrated superior identification performance independent of identification modality. Notably, no correlations were observed between cognitive style and performance for participants learning to recognize simple objects.

These findings reaffirm the possibility that haptic exploration may facilitate a more complex memory representation, which is accessible to both sight and touch during object identification. However, given that haptic perception is not attuned for processing specific sets of features in the same manner as vision (Lakatos & Marks, 1999), it is unlikely that this complex representation is attributable to somatosensation on a physiological level. Rather, this overlapping memory representation may be driven by the nature of haptic exploration itself. Unlike visual identification, which naturally occurs in a collective manner such that an entire object can be viewed at once, haptic identification is performed serially and incorporates more deliberate exploratory procedures, such as edge following (Lederman & Klatzky, 1987). In doing so, more attention may be allocated toward spatial relationships between an object’s features.

When learning to recognize complex objects, attending to minute spatial relationships between local features is advantageous, as their lack of global features renders our visual system's holistic representations for objects to be less salient (Lakatos & Marks, 1999). This is especially the case when learning to recognize complex objects by touch. On the one hand, complex objects cannot easily be described verbally, limiting our ability to encode these objects using verbal mechanisms. Similarly, when participants learn to recognize object by touch, they cannot rely on holistic visual information. As Lacey and Campbell (2006) note, restricting one mechanism during object encoding (e.g., verbal or visual) generally forces us to rely more on alternative mechanisms (e.g., spatial). For spatial-imagers, whose most effective method for obtaining and applying information relies on spatial mechanisms, these circumstances are ideal. By exploring complex objects by touch, they will be able to gradually build a schematic representation of each object (Blazhenkova & Kozhevnikov, 2009). Conversely, object-imagers and verbalizers will be forced to rely on perpetual information that is less salient to them, thereby degrading identification performance.

The current study examined the types of information used to create visuo-haptic object representations in memory, and whether this depends on individual differences in cognitive style. Generally, we found that participants learning to recognize complex objects produced more errors and required more blocks to reach criterion compared to those learning simple objects. Participants who completed the task without distraction displayed superior identification performance compared to those who experienced a visuospatial distractor, especially when identifying complex objects. Finally, we demonstrated that a spatial-imager cognitive style leads to greater identification performance regardless of identification modality when learning complex objects by touch. Overall, these findings suggest that the types of information used to form object representations in memory are determined by the cognitive style of the individual, as well as the types of objects being learned, and the modality in which encoding occurs.

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