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Look but don't touch: Tactile disadvantage in processing modality-specific words

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ABSTRACT

Recent neuroimaging research has shown that perceptual and conceptual processing share a common, modality-specific neural substrate, while work on modality switching costs suggests that they share some of the same attentional mechanisms. In three experiments, we employed a modality detection task that displayed modality-specific object properties (e.g., unimodal *shrill*, *warm*, *crimson,* or bimodal *jagged*, *fluffy*) for extremely short display times and asked participants to judge whether each property corresponded to a particular target modality (e.g., auditory, gustatory, tactile, olfactory, visual). Results show that perceptual and conceptual processing share a tactile disadvantage: people are less accurate in detecting expected information regarding the sense of touch than any other modality. These findings support embodied assertions that the conceptual system uses the perceptual system for the purposes of representation. We suggest that the tactile disadvantage emerges for linguistic stimuli due to the evolutionary adaptation of endogenous attention to incoming sensory stimuli.

1. Introduction

How do we think about objects that are not in front of us at the time? Do we see with the mind's eye and touch with the mind's fingers? Embodied theories of cognition hold that conceptual thought is grounded in the same neural systems that govern sensation, perception and action (Barsalou, 1999, 2008; Gibbs, 2003; Glenberg, 1997; Wilson, 2002). Barsalou's (1999) Perceptual Symbol Systems, for example, describes concepts as partial recordings of the neural activation that arises during perceptual and motor experiences, where these recordings can later be re-enacted as a perceptual simulation of a particular concept.

Recent neuroimaging work has provided evidence that perceptual experience and conceptual knowledge share a common, modality-specific neural substrate. For example, using fMRI, González and colleagues (2006) found that passively reading scent-related words (e.g., *cinnamon*) increased activation in the primary olfactory areas of the piriform cortex. Regarding visual processing, Simmons et al. (2007) showed that verifying colour properties in text (e.g., that a banana is *yellow*) led to activation in the same region of the left fusiform gyrus in the visual cortex as a perceptual task that involved judging colour sequences. Further comparisons by Goldberg, Perfetti, and Schneider (2006) found that verification of colour, sound, touch, and taste properties activated cortical regions, respectively, associated with encoding visual, auditory, tactile and gustatory experiences.

Our perceptual and attentional systems are intertwined, giving attention the power to direct perceptual processing towards modality-specific goals, both exogenously (where incoming stimuli automatically and obligatorily grab attention) and endogenously (where people consciously focus attention on a particular modality). In addition to sharing a neural substrate, it seems that exogenous attentional mechanisms, at least, are shared by the perceptual and conceptual systems. For example, when Spence, Nicholls and Driver (2001, see also Turatto, Galfano, Bridgeman,

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& Umiltà, 2004) asked people to respond to a series of perceptual stimuli, they found that switching modalities from one trial to the next (e.g., from a visual light flash to an auditory tone) incurred a processing cost. Similarly, when Pecher, Zeelenberg and Barsalou (2003; see also Lynott & Connell, 2009; Marques, 2006; van Dantzig, Pecher, Zeelenberg, & Barsalou, 2008) asked people to verify a series of unimodal object properties presented as text onscreen, they found that people were slower to verify a property in a given modality (e.g., auditory *leaves:rustling*) after verifying a property in a different modality (e.g., visual *apple:shiny*) compared to the same modality (e.g., auditory *blender:loud*). In both perceptual and conceptual tasks, such modality switching costs are thought to result from the re-allocation of exogenous attention from one modality-specific system to another.

If the conceptual system has co-opted the perceptual system for the purposes of representation, then it follows that one should expect modality-specific perceptual (and attentional) phenomena to emerge in conceptual processing. One such phenomenon is the tactile disadvantage in perceptual processing, relative to vision and audition. When people are asked to respond to the arrival of a perceptual stimulus, they are generally slower to detect tactile stimuli (e.g., finger vibration) than visual (e.g., light flash) or auditory (e.g., noise burst) stimuli, even when they are told which modality to expect (Spence et al., 2001; Turatto et al., 2004). In other words, asking people to focus their endogenous attention on a particular sensory modality creates anticipatory activation in the relevant area of the cortex (Foxe, Simpson, Ahlfors, & Saron, 2005) and allows information from that modality to be processed more quickly, but expected tactile stimuli still take longer to process than expected visual or auditory stimuli.

So why should tactile processing be disadvantaged? There are obvious physiological differences in processing stimuli from different perceptual modalities, with differential latencies for transduction in the skin, retina, and cochlea, and for transmission of their respective signals to the somatosensory, visual, and auditory cortices. However, since the retina is actually the slowest of the three in converting a stimulus to an electrical signal and delivering it to the brain, these physiological differences alone cannot explain the tactile disadvantage in stimulus perception. Rather, the tactile modality appears to be disadvantaged when it comes to the resolution of the raw sensory signal into a recognisable percept. Recent perceptual research has also suggested that tactile endogenous attention operates differently to attention on other modalities; when Karns and Knight (2009) examined how endogenous attention affected processing of visual, auditory and tactile stimuli, they found that attention modulated ERPs at early latencies for visual (62 ms) and auditory (29 ms) processing, but did not modulate tactile ERPs until much later (165 ms). This lag in attentional modulation suggests that selective focus on touch may not impact on the formation of tactile representations quite as effectively as similar focus affects other modality-specific representations. Researchers have speculated on a number of reasons why attention on the sense of touch might be a special case. The tactile modality may be special in requiring a "personal space" representation of the body, in contrast to the visual or auditory modalities requiring a peripersonal or extrapersonal representation of the world, and hence may require a different attentional perspective (Martin, 1995; Spence et al., 2001). For example, if something is being felt by touch, it is (by definition) located on the body's surface, and there may be costs involved in shifting attentional perspective to something that is seen or heard some distance away. Alternatively, there may be an adaptive advantage in coupling attention longer to visual and auditory modalities than to tactile (Turatto et al., 2004). In this account, approaching threats could be efficiently detected at a safe distance by keeping attention focused on sight or sound, but waiting to detect a potential danger by touch is unlikely to have evolved as a useful attentional mechanism.

The present study aimed to investigate whether the tactile disadvantage in perceptual processing also emerges during conceptual processing. In three experiments, we used a modality detection task to examine endogenous attention during the conceptual processing of modality-specific words. The modality detection task measures accuracy rates for extremely short display times above the subliminal threshold and is a variant of that previously used to examine the positive/negative detection of emotionally affective words (Dijksterhuis & Aarts, 2003). In Experiments 1 and 2, participants were presented with unimodal object properties (i.e., perceived through one sense alone) for a range of increasing display times and were asked to judge whether the property corresponded to a target modality (auditory, gustatory, tactile, olfactory, or visual). Experiment 3 used the same paradigm to compare unimodal and bimodal object properties (i.e., perceived equally through two senses) for visual and tactile target modalities.

2. Experiment 1: unimodal properties in yes/no task

In the modality detection task, participants first saw blocks for each modality (auditory, gustatory, tactile, olfactory, visual) for an extremely short display time at the threshold of subliminal perception (17 ms), then the blocks were repeated for increasing display times (33 ms, 50 ms, 67 ms, 100 ms). We expected accuracy rates to improve over successive repetitions, both because of practice effects and because longer display times increase the probability of successful detection. Importantly, following findings for perceptual stimuli (Spence et al., 2001; Turatto et al., 2004), we predicted more accurate detection of visual and auditory properties than tactile properties (i.e., the tactile disadvantage). Indeed, since previous work (Dijksterhuis & Aarts, 2003; Gaillard et al., 2006) has shown that conceptual processing of affective valence occurs before conscious access, we expected to see the tactile disadvantage even for subliminal presentation (i.e., the shortest 17–33 ms blocks).

Predictions for gustatory and olfactory properties varied according to the reasons researchers have offered for why tactile processing may be disadvantaged. Since the sense of taste presumably requires a representation in personal