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Aging and solid shape recognition: Vision and haptics

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ABSTRACT

The ability of 114 younger and older adults to recognize naturally-shaped objects was evaluated in three experiments. The participants viewed or haptically explored six randomly-chosen bell peppers (*Capsicum annuum*) in a study session and were later required to judge whether each of twelve bell peppers was "old" (previously presented during the study session) or "new" (not presented during the study session). When recognition memory was tested immediately after study, the younger adults' (Experiment 1) performance for vision and haptics was identical when the individual study objects were presented once. Vision became superior to haptics, however, when the individual study objects were presented multiple times. When 10- and 20-min delays (Experiment 2) were inserted in between study and test sessions, no significant differences occurred between vision and haptics: recognition performance in both modalities was comparable. When the recognition performance of older adults was evaluated (Experiment 3), a negative effect of age was found for visual shape recognition (younger adults' overall recognition performance was 60% higher). There was no age effect, however, for haptic shape recognition. The results of the present experiments indicate that the visual recognition of natural object shape is different from haptic recognition in multiple ways: visual shape recognition can be superior to that of haptics and is affected by aging, while haptic shape recognition is less accurate and unaffected by aging.

1. Introduction

Few studies have compared the visual and haptic recognition of objects with natural shapes. In one previous experiment (Experiment 1 of Norman, Norman, Clayton, Lianekhammy, & Zielke, 2004), participants could reliably (with 70–72% accuracy) identify objects visually that had the same shapes as those examined haptically. A sizeable number of studies, in comparison (e.g., Craddock & Lawson, 2009; Newell, Ernst, Tjan, & Bülthoff, 2001; Pensky, Johnson, Haag, & Homa, 2008), have evaluated the visual and haptic recognition of *manmade* objects (e.g., configurations of legos; collections of objects, such as alarm clocks, batteries, cars, spoons, hair brushes, hammers, scissors, tweezers, etc). These studies found either that visual and haptic object recognition performance was similar (Craddock & Lawson, 2009; Newell et al., 2001) or that visual object recognition was superior (Pensky et al., 2008). These investigations are obviously important, because of the frequency with which we perceive and interact with manmade objects. Nevertheless, manmade objects commonly lack essential component (s) of solid shape that many natural objects possess. Natural objects (e.g., consider the replicas of bell peppers presented in Fig. 1) are often *intrinsically curved* and possess two generic types of curved surface regions, which can be described as *elliptic* and *hyperbolic* (Hilbert & Cohn-Vossen, 1983; Koenderink, 1990; Koenderink & van Doorn, 1982). Elliptic surface regions are curved like the outside or inside of an egg or sphere, while hyperbolic surface regions are curved like a horse's saddle. One can think of hyperbolic regions as serving as a kind of "glue" that binds elliptic regions together into a coherent and unitary object (e.g., see Koenderink, 1990, p. 601; also see Fig. 4 of Lappin, Norman, & Phillips, 2011). The shapes of manmade objects are frequently very different: manmade objects often consist of either flat or cylindrical surface regions (e.g., bricks, water bottles, staplers, flashlights, coffee mugs, flower pots, etc). Cylindrical surfaces, while possessing *extrinsic curvature* (curved with respect to an outside coordinate system), are not intrinsically curved. To demonstrate this, imagine cutting a paper or cardboard cylinder along its noncurved dimension: it would then be quite easy to "roll out" the cylinder to form a flat, noncurved plane. A cylindrical surface, therefore, lacks intrinsic curvature and is very different from truly curved surfaces, such as elliptic and hyperbolic regions (one cannot take elliptic or hyperbolic surfaces and flatten them without either tearing the surface or wrinkling it up, see Koenderink, 1990, pp. 264–265).

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Fig. 1. Photographs of the 12 naturally-shaped objects (replicas of bell peppers, *Capsicum annuum*) used as stimuli in Experiments 1–3. Object 13 is located at the top left. The objects progress numerically in order from top-left to bottom-right; object 24, therefore, is located at the bottom right.

While previous studies have investigated the visual and haptic recognition of manmade objects, there is little to no existing literature regarding the recognition of naturally-shaped objects that possess elliptic and hyperbolic surface regions. One goal of the current investigation was to fill this void.

Ballesteros and Reales (2004) evaluated haptic (but not visual) object recognition and aging. They used familiar objects, mostly manmade, such as books, coins, drinking glasses, a tobacco pipe, etc. Ballesteros and Reales found no significant difference in recognition performance between younger adults (mean age was 29.3 years) and healthy older adults (mean age was 74.7 years). Participants in both age groups performed at essentially perfect levels of recognition accuracy (mean number of hits–false alarms was 9.58 and 8.5 out of a maximum of 10 for younger and older participants, respectively).

Given the current state of the literature, a number of unresolved questions remain. Do the previously obtained results comparing visual and haptic recognition for manmade objects generalize to the recognition of naturally-shaped objects? Do the results obtained for younger adults for both vision and haptics generalize to older adults, or do significant age differences exist? The purpose of the current set of experiments was to answer these questions. Experiments 1 and 2 were conducted to evaluate the capabilities of younger adults, while the purpose of Experiment 3 was to investigate the potential effects of aging.

2. Experiment 1

2.1. Method

2.1.1. Apparatus

The order of the experimental stimuli for each participant (for both object study and test sessions) were determined by an Apple PowerMacintosh G4 computer. The participants' judgments were entered into the computer for later analysis.

2.1.2. Experimental stimuli

Liquid rubber was used to make molds of 12 natural bell peppers (*Capsicum annuum*). The bell peppers had similar sizes (e.g., mean top-to-bottom size was 12.5 cm, sd = 0.6), but different shapes. Solid (positive) copies of the bell peppers were created