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Manual preferences for visually- and haptically-guided grasping

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ABSTRACT

Studies have shown that individuals exhibit a right-hand preference for grasping during visually-guided tasks. Recently, we have found that when vision is occluded right-hand preference decreases dramatically. It remains unknown however, if this decrease is a result of visual occlusion or the effects of relying only on haptic feedback. Therefore, in the present study, we sought to explore the contributions of vision and haptics (separately *and* in conjunction) to hand preference for grasping. Right- and left-handed individuals were tested on a block building task under four different visual and haptic conditions: 1) vision/normal haptic feedback (V/H), 2) no vision/normal haptic feedback (NV/H), 3) vision/constrained haptic feedback (V/Constrained-H), and 4) no vision/constrained haptic feedback (NV/Constrained-H). Vision was occluded using a blindfold and haptic feedback was constrained by asking participants to wear textured gloves. Right-handed individuals displayed a right-hand preference when vision was available (V/H and V/Constrained-H groups), but this preference was much greater when haptic feedback was constrained (V/Constrained-H group). When vision was occluded and haptic feedback was used to complete the task (NV/H) no hand preference was found. Finally hand preference was similar between the V/H and the NV/Constrained-H groups. For left-handed individuals, no differences in hand use were found between the different sensory groups, but the NV/H group showed a clear left-hand preference for haptically-guided grasping. The results suggest that haptics plays an important role in hand preference for grasping. Furthermore, they support a left-hand/right-hemisphere specialization for haptically-guided grasping (regardless of handedness) and a right-hand/left-hemisphere specialization for visually-guided grasping (at least in right-handed individuals).

1. Introduction

Research has shown that vision plays a pivotal role in guiding goal-directed movement. In fact, it has been argued that the primary reason vision evolved was for the distal control of movement (Goodale, 1983). Kinematic analyses have confirmed the importance of visual feedback during goal-directed movement, and in particular, the reach-to-grasp action. When vision is occluded, individuals display larger maximum grip apertures (Jackson, Jackson & Rosicky, 1995; Jakobson & Goodale, 1991; Rand, Lemay, Squire, Shimansky & Stelmach, 2007), slower movement times (Schettino, Adamovich & Poizner, 2003; Winges, Weber & Santello, 2003), and a decrease in task accuracy, to the degree that the hand often collides with the target object (Wing, Turton & Fraser, 1986) or misses the target completely (Babinsky, Braddick & Atkinson, 2012). In contrast, in the presence of vision, individuals show improved endpoint accuracy (Westwood, Heath & Roy, 2003), correct object size scaling (Keefe & Watt, 2009), and enhanced movement regulation (Saunders & Knill, 2003; Tremblay, Hansen, Kennedy & Cheng, 2013). Not surprisingly, vision also plays a critical role in hand preference for grasping. During visually-guided grasping tasks, individuals (even some left-handed) exhibit a clear preference to grasp objects with the right-hand (Bishop, Ross, Daniels & Bright, 1996; Bryden & Roy, 2006; Calvert & Bishop, 1998; Gabbard & Rabb, 2000; Gonzalez & Goodale, 2009; Jacquet, Esseily, Rider & Fagard, 2012; Stone & Gonzalez, 2014a; Stone, Bryant & Gonzalez, 2013). The role of haptics in hand preference for grasping however, has been seldom investigated. Haptics is the perception of combined tactile and kinesthetic inputs during object manipulation and exploration (Grunwald, 2008; Keysers, Kaas & Gazzola, 2010; Lederman & Klatzky, 2009). Kinematic studies of haptically-guided grasping have shown that pre-shaping of the hand could be as accurate as when guided by vision (Karl, Sacrey, Doan & Whishaw, 2012). So although this information suggests that haptics can effectively be used to guide reach-to-grasp movements, the contribution of haptics to hand preference remains unknown. Is there a right-hand preference during haptically-guided grasping as there is during visually-guided grasping?

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We recently investigated this question using the block building task (Gonzalez & Goodale, 2009; Stone & Gonzalez, 2014a,b; Stone et al., 2013) and found that when individuals are blindfolded and must use only their sense of touch to complete the task (rendering it a haptically-guided task), no hand preference is observed (Stone & Gonzalez, 2014a,b). As haptic discrimination of the building blocks plays a central role in the task, these results pose the question: is this decrease in right-hand use (or increase in left-hand use) due to a left-hand advantage for haptic discrimination? Several studies have shown a left-hand advantage for haptic discrimination. In these studies, individuals have been asked to tactically identify numbers (Heller, Rogers & Perry, 1990) and letters (O'Boyle, Van Wyhe-Lawler & Miller, 1987, including Braille: e.g. Hermelin & O'Connor, 1971; Wilkinson & Carr, 1987) or haptically assess and discriminate between object properties including: thickness (Cormier & Tremblay, 2013), roughness (Tomlinson, Davis, Morgan & Bracewell, 2011), curvature (Squeri et al., 2012), shape (Fagot, Hopkins & Vauclair, 1993a; Fagot, Lacreuse & Vauclair, 1993b), or hardness (Morange-Majoux, 2011) for various objects. For instance, O'Boyle et al. (1987) traced capital letters onto the palms of individuals and found that accuracy was higher when the letter was traced onto the left hand. Also, Heller et al. (1990) found that individuals were more accurate at identifying numbers on a vibrotactile display with the left hand (when compared to the right hand). In fact, evidence for this advantage emerges in infancy. When infants (4 to 6 months of age) are given a cylinder to explore, the left hand spends more time than the right hand touching the object, which was suggested as a left-hand advantage for haptic processing (Morange-Majoux, 2011). Patient studies show that individuals with right- but not left-hemisphere damage show bilateral impairment on tactile tasks, attributing the findings to a left-hand/right-hemisphere advantage for haptic processing (Cannon & Benton, 1969; Fontenot & Benton, 1971; Milner & Taylor, 1972; Zaidel & Sperry, 1973). Together this evidence suggests that the right hemisphere plays a pivotal role in haptic processing.

In Stone and Gonzalez (2014a,b), occluding vision during a grasping task revealed a decrease in right-hand use (inevitably resulting in an increase in left-hand use). Because vision is our dominant source of sensory information (Atkinson, 2000; Rock & Victor, 1964), it is possible that the decrease in right-hand use is exclusively related to the lack of visual feedback. Alternatively, because without vision participants had to rely on haptics to complete the task, the decrease in right-hand use could be due to the left-hand/right-hemisphere specialization for haptic processing. Furthermore, it remains unknown if or how this specialization presents in left-handed individuals. Therefore, in the present experiment, we investigate the contributions of vision and haptics (separately *and* in conjunction) to hand preference for grasping in a right- and a left-handed population.

Right- and left-handed individuals were tested on the block building task (see Gonzalez, Whitwell, Morrissey, Ganel & Goodale, 2007; Stone & Gonzalez, 2014a; Stone et al., 2013). Participants in four different groups (Vision/normal haptic feedback (V/H), No Vision/normal haptic feedback (NV/H), Vision/constrained haptic feedback (V/Constrained-H), No Vision/constrained haptic feedback (NV/Constrained-H)) were asked to replicate 3D models from a tabletop of evenly distributed building blocks. Vision was occluded by using a blindfold and haptics was constrained by using textured fitted gloves. If vision is the primary modulator of hand preference for grasping then manipulating haptic feedback should have little to no effect on this preference. In other words groups V/H and V/Constrained-H should show similar rates of right-hand use. However, if haptic feedback is important for hand selection these two groups should be different. If there is a left-hand advantage for processing haptic information we expect to see a decrease in left-hand use in the V/Constrained-H when compared to the V/H group. Hand preference for grasping was documented in ipsilateral (same side as the hand) and contralateral (opposite side of the hand) space.

2. Experiment One (right-handers)

2.1. Methods and procedures

2.1.1. Participants

Eighty self-reported right-handed individuals (29 males) were recruited for this study. Seventy-eight participants were from the University of Lethbridge between the ages of 18 and 33 and participated in exchange for course credit. Two students were recruited from a local high school (2 females, aged 16 and 17). Twenty participants were randomly assigned to each of the four test groups: Vision/normal haptic feedback (V/H), No Vision/normal haptic feedback (NV/H), Vision/constrained haptic feedback (V/Constrained-H), and No Vision/constrained haptic feedback (NV/Constrained-H). All participants gave written informed consent in accordance with the Declaration of Helsinki and the approval of the University of Lethbridge Human Subjects Research Committee (protocol #2011-22) before participating in the study. Participants were naïve to the purposes of the study and able to withdraw at any time without consequence.

2.1.2. Apparatus and stimuli

2.1.2.1. Handedness questionnaire. A modified version of the Edinburgh (Oldfield, 1971) and Waterloo (Brown, Roy, Rohr & Bryden, 2006) handedness questionnaires were given to all participants at the end of the block building task. This version included questions on hand preference for 22 different tasks (see Appendix 1). Participants had to rate which hand they prefer to use for each task on a scale $+2$ (right always) $+1$ (right usually), 0 (equal), -1 (left usually) and -2 (left always). Each response was scored as (2, 1, -1, or -2) and a total score was obtained by adding all values. Possible scores range from $+44$ for exclusive right-hand use to -44 for exclusive left-hand use.

2.1.2.2. Block building task. A total of three models built with LEGO® blocks were used for the experiment. These blocks ranged in size from <1.5 L × 0.7 W × 1.0 cm H to 3.1 L × 1.5 W × 1.0 cm H. Each model contained 10 blocks of various colors and shapes (see Supplementary material for a picture of models used). Scattered on a table (122 L × 122 W × 74 cm H with a working space of 70 L × 122 W × 74 cm H) were all the blocks that made up the three models. The models were prepared ahead of time by the experimenter. The same three models were used with all participants. The same number of blocks was placed on the left and right side of the table. There was a fixed building plate (19 L × 19 cm W) located within arms' length of the participant. Additionally, there was an exact duplicate of this building plate in the front and center of the participant. The far plate had the model to be replicated attached to it, and the near plate was used for the construction of the new model (see Fig. 1 for an example of the display).

2.1.3. Procedures

Participants were seated in front of the table facing the middle of the display which was covered by an opaque tablecloth. To assess how vision and/or haptics affected hand preference for grasping, prior to task initiation, sensory (vision or haptics) availability was manipulated. Individuals either put on a blindfold (NV/H), a pair of Atlas Fit 300™ textured rubber gloves (V/Constrained-H), or a blindfold *and* a pair of textured rubber gloves (NV/Constrained-H). Those in the V/H group did not wear a blindfold or gloves and completed