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Forward displacement in grasping and visually judging pliers

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Observers often tend to misremember the visual stopping point of a movement in the direction of movement (representational momentum). We investigated whether this forward displacement also occurs in grasping. We asked participants to close virtual pliers after the pliers had been opening or closing. The participants' thumbs and index fingers were attached to robot arms which allowed us to provide haptic feedback about the location of the pliers' handles. In a visual task, participants judged the remembered final opening width of the pliers relative to a comparison stimulus. For grasping, we found forward displacement: participants opened their fingers wider if the pliers had been opening compared to when they had been closing. In contrast, we did not find clear forward displacement in the visual task. The effects in grasping and the visual task were not correlated between participants. These results seem to argue against the existence of one form of anticipation that serves both perception and grasping.

INTRODUCTION

Freyd and Finke (1984) presented observers with three discrete visual presentations of a rotating rectangle. Each rectangle was rotated a certain amount further compared to the one before. The observers were asked to judge whether a fourth rectangle was the same as the third or not. When the fourth rectangle was rotated slightly further in the direction of rotation than the third rectangle, observers more often judged them to be the same compared to when the fourth

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rectangle was rotated slightly in the direction opposite to the direction of rotation. Freyd and Finke called this tendency to judge the stopping point of an object as being further forward in the direction of motion 'representational momentum'. They proposed that, just like moving objects in the world possess momentum, the brain is not able to immediately stop mentally extrapolating the position of a moving target. Whether this is the proper explanation or description of the phenomenon has been debated, so we will use the more neutral term 'forward displacement'.

Regardless of the mechanism behind it, forward displacement has been demonstrated in many other studies (for reviews see Hubbard, 1995c; for a recent collection of related work see Thornton & Hubbard, 2002). These include studies in which different stimuli were used, such as translating objects (Hubbard & Bharucha, 1988), groups of translating objects (Finke & Shyi, 1988) and crowds of human figures (Thornton & Hayes, 2004). Additionally, the effect has been demonstrated using other measures besides the one described above, such as adjustments of a comparison (Jordan, Stork, Knuf, Kerzel, & Müsseler, 2002), positions indicated with a mouse (Hubbard & Bharucha, 1988) and patterns of reaction times (Freyd, 1983; Verfaillie & Daems, 2002). Kerzel showed that several factors affect the strength of the effect, including the observer's expectations about the target's movement (Kerzel, 2002), eye movements (Kerzel, 2000) and the smoothness of the target's motion (Kerzel, 2003).

Forward displacement may be considered as an anticipation effect or an 'automatic prediction' of the future state of an object which could facilitate interacting with that object (Brouwer, Middelburg, Brenner, & Smeets, 2003; Hubbard, 1998; Nagai, Kazai, & Yagi, 2002). As Hubbard (1998) pointed out, a response to a stimulus should ideally be tailored to how the stimulus will be at the time of the response, not to how the stimulus was at the time when the process of decision and response began. Hubbard demonstrated other kind of displacements which are consistent with this notion, such as 'representational gravity' (a downward moving target is displaced more in the direction of motion than an upward moving stimulus; Hubbard, 1990) and 'representational friction' (less forward displacement when a target slides across a stationary surface than when it moves freely; Hubbard, 1995a). All these kinds of displacement may reflect predictions about the target's movement. If forward displacement evolved because it provides an advantage in the interaction of an observer with a constantly changing world, then we should be able to find this effect not only in perception, but also in action.

In the present study we investigated whether forward displacement can be found when grasping an object that has been changing. Specifically, we presented participants with implied visual sequences depicting the opening or closing of a pair of household pliers. We asked participants to reach out and close the finally presented virtual pliers just after the pliers had vanished in order to see whether the direction of change affected grasping behaviour. We also measured visual performance using the same changing object in a standard forward displacement comparison task.

Other studies have investigated forward displacement in tasks which involved action such as pointing at the location where a moving target disappeared using a mouse (Hubbard & Bharucha, 1988; Kerzel, 2003), a trackball (Motes, Hubbard, & Courtney, 2005) or the index finger (Kerzel, 2003; Motes et al., 2005). The studies by Kerzel (2003) and Motes et al. (2005) suggested a stronger forward displacement for pointing with the finger than for a comparable visual task. We think that grasping a target could be considered as being a still more typical action than pointing with the finger to a remembered location.

For visual judgment tasks, the way of measuring forward displacement is well established. This is not the case for grasping. However, grasping is a very well studied behaviour. Following Jeannerod (1981, 1984), reach to grasp movements are often described as consisting of a transport and a grip component (although it is doubted whether or to what extent these components are really separate; Alberts, Saling, & Stelmach, 2002; Chieffi & Gentilucci, 1993; Jakobson & Goodale, 1991; Smeets & Brenner, 1999). The transport component refers to bringing the hand to the target whereas the grip component refers to the movement of the fingers and thumb during the transport. For grasping with thumb and index finger, people consistently start increasing the distance between thumb and finger until a certain maximum is reached, between 60% and 80% of the movement time (Jeannerod, 1984). Then they decrease this aperture again until their fingers touch the object. Thus, the maximum grip aperture is larger than the distance between the contact points of the thumb and index finger with the object. However, it scales linearly with object size with a scale factor that depends on the specific circumstances but is usually about 0.8 (reviewed by Smeets & Brenner, 1999). That is, an increase of an object's size of 1 cm will generally increase the maximum grip aperture with about 8 mm. Studies in which participants grasp objects after switching shutter glasses to an opaque state (Westwood, McEachern, & Roy, 2001) or even after removing the whole target object such that participants pantomime the grasping movement (Goodale, Jakobson, & Keillor, 1994) indicate that maximum grip aperture also scales with object size when grasping memorized objects. The scaling property of grasping has been often used to investigate whether illusory size is used in grasping (e.g., Aglioti, DeSouza, & Goodale, 1995; Brenner & Smeets, 1996; Franz, Gegenfurtner, Bülthoff, & Fahle, 2000; Glover & Dixon, 2002; Westwood et al., 2001). In such studies, the maximum grip aperture toward two targets of the same physical size but in different illusory contexts is compared. This difference in maximum grip aperture is compared to the difference in maximum grip aperture that is induced by a physical size difference (the scale factor). Similarly, in our study, we investigate to what extent the direction of motion (opening versus closing) affects the maximum grip aperture, relative to the effect of an actual size difference.

METHODS

Stimuli and apparatus

The visual appearance of the stimuli in the grasping task was identical to the visual appearance of the stimuli in the visual task and consisted of three successively presented photographs of a pair of household pliers (see Figure 1). The sequence could either imply opening or closing pliers in steps of about 1 cm as measured between the tips of the handles. The distance between the tips of the handles of the third pliers (target pliers) could be either 37 mm or 47 mm (target width). The pliers were photographed on a squared grey surface (10.5 $\times$ 10.5

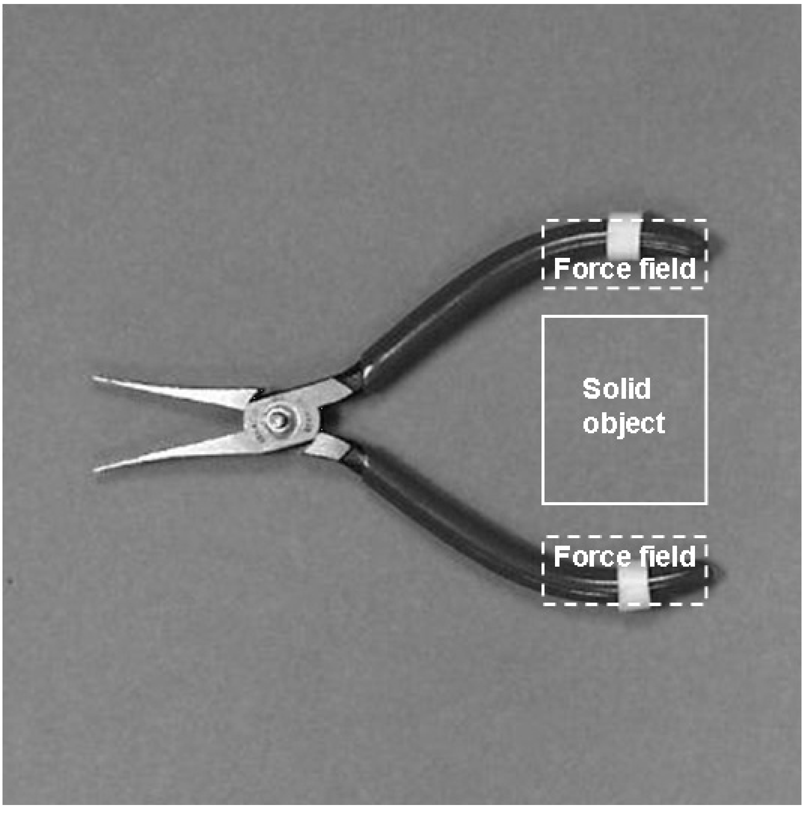

Figure 1. The stimulus pliers. The actual stimulus was a full-colour picture. The white outlines indicate the size and position of the simulated haptic objects.

cm), which in turn was presented on a black background. Each photograph was presented for 250 ms. Between every two photographs, the grey square was presented alone, without the pliers, for 250 ms. These intervals and the presentation times of the photographs gave rise to an implied motion sequence (as opposed to apparent motion).

Figure 2 shows an overview of the experimental apparatus, which involved stereo-computer graphics (Open GL and Crystal Eye shutter glasses), two robot arms (Phantom™) and a mirror setup. Participants were seated on a chair and looked down into the mirror through shutter glasses. The monitor hanging above the mirror was used to present the sequence of opening or closing pliers so that they appeared to be on the left of a horizontal plane just above waist-level. The pliers were rendered as 2D images in the monitor plane, at a distance of approximately 50 cm from the participants' eyes. Thus, 1 cm on the monitor plane corresponded to about 1.1 degree of visual angle.

Procedure

Half of the participants performed the grasping task first, the other half performed the visual judgment task first.

Grasping task

During the grasping task, the thumb and the index finger of the participants' right hand were attached to the two Phantoms. The positions of the tip of the thumb and the tip of the index finger in space were indicated by two stereoscopically presented spheres. To start a trial, the participants had to bring these spheres within a starting area that was specified by a larger stereoscopically presented sphere. This ensured that participants started the grasping movement with the tips of index finger and thumb close to each other. The starting area was about 15 cm to the right of the pliers. If the fingers were in the correct position, the large sphere disappeared. The participants' task was to watch the sequence of opening or closing pliers, and after the target pliers had disappeared, to reach out and close the pliers (aiming for the white marks on the handles). Figure 1 indicates the relative size and position of three (invisible) haptic objects: two force field objects and one solid object. The objects were all 2.5 cm high (as defined along the axis rising up from the surface on which the pliers were lying). If participants touched the haptic objects, or the surface on which the pliers were lying, the phantoms provided resistance to make the pliers and the surface appear physically present. To close the pliers, participants had to move their fingers through 'force field' objects (exerting a constant force outward of 0.8 N) until they collided with a simulated solid object which represented the closed pliers. We created small gaps between the force fields and the simulated solid object, so that the participants did not experience a force pushing their fingers back after having closed the pliers. This avoided the haptic impression of pliers

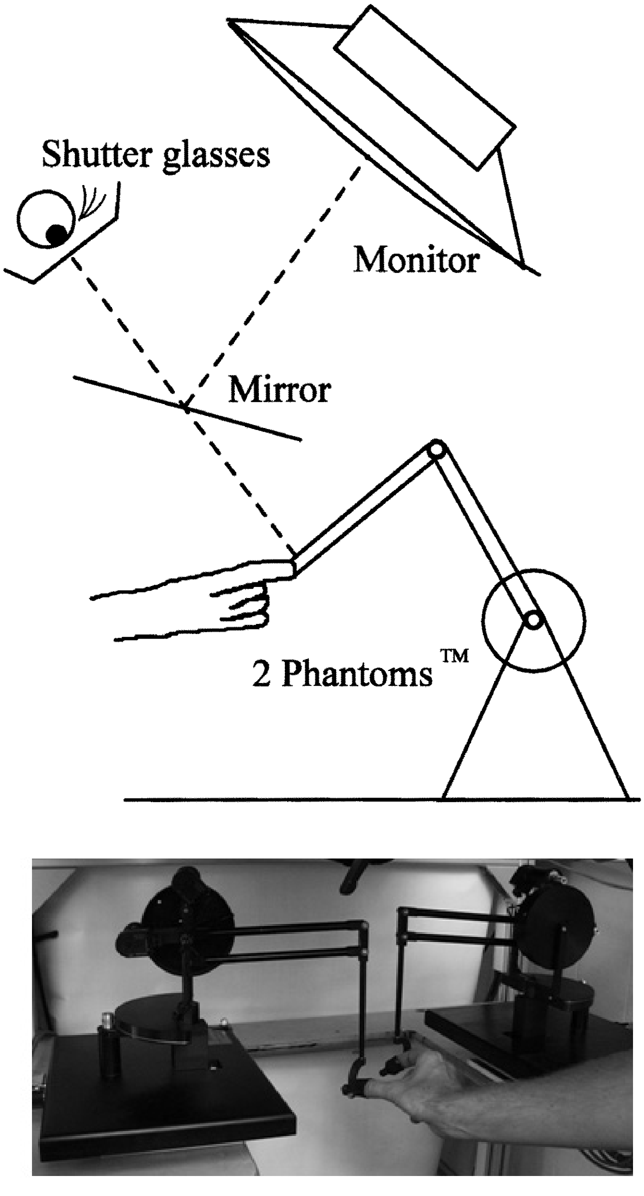

Figure 2. Overview of the experimental setup. The Phantoms were only used in the grasping task.

that ‘spring’ open. For the experimental trials, the pliers were invisible during the whole time that the participant performed the reaching and closing action.

There were 2 (direction; opening or closing) $\times$ 2 (target width; 37 or 47 mm) = 4 conditions. The trials were presented in two blocks with a break in between. In each block, every condition was repeated 20 times in random order (with a new random order for each new block). Every participant thus performed 160 grasping trials. Before the actual experiment started, the participants practised 12 trials in which the pliers always remained visible. After that, they practised an additional 16 trials which were exactly the same as in the actual experiment. In these trials, participants were only allowed to start moving their hand after the pliers had disappeared and only the grey square had remained. If participants started moving away from the starting area before the pliers had disappeared, they received a warning that they started too early and the trial was repeated later. If the participants did not close the pliers within 3 seconds of the pliers’ vanishing, they were warned that they were too late and the trial was repeated later. A successful closing was indicated by the short reappearance of the (now closed) pliers.

Visual task

Visual performance was measured using the traditional forward displacement comparison task. The visual stimuli were exactly the same as in the grasping task, except for that a pair of comparison pliers was shown after the three inducing pliers. Between the third pliers and the comparison, the empty grey background was presented again for 250 ms. The comparison pliers could either be the same as the target pliers, or they could be one to four steps more closed or one to four steps more open. One step corresponds to about 2.5 mm difference in opening width as measured between the tips of the handles. We asked the participants to watch the sequence, and to indicate whether the opening width of the third (target) pliers was equal or not to the fourth (comparison) pliers by pressing the appropriate button on a keyboard which they had on their lap. It was explained that the percentage of ‘equal’ and ‘not equal’ responses needed not be the same (in fact, the comparison was equal to the target pliers in 11% of the trials). The comparison pliers remained visible until the participant responded or until the comparison pliers had been presented for 3 seconds. In the latter case, the message ‘too late’ appeared and the trial was repeated later.

There were 2 (direction; opening or closing) $\times$ 2 (target width; 37 or 47 mm) $\times$ 9 (comparison; one to four steps more closed than the target, one to four steps more open or equal) = 36 conditions. The trials were presented in two blocks with a break in between. In each block, every condition was repeated 5 times in random order (with a new random order for each new block). Every participant thus performed 360 visual trials. Before the actual experiment started, the participants practiced two blocks of 16 trials each. The participants did not receive feedback, either during the practice or during the experiment.

Participants

Fourteen right-handed participants performed the tasks. Their ages varied from 20 to 40 years, with a mean of 27. They were paid for their participation.

RESULTS

Analysis

Grasping task

For each grasping trial, we calculated the maximum distance between thumb and index finger. We used a repeated measures ANOVA with direction and target width as within subject factors, and task order (whether the visual task or the grasping was performed first) as a between subject factor. Forward displacement would be consistent with a larger maximum grip aperture when opening pliers are grasped than when closing pliers are grasped.

Visual task

To estimate the remembered opening width of the target pliers in the visual judgment task, we computed the ‘remembered width’. This was the weighted mean (Faust, 1990; Hayes, 1997) for every participant for each of the four (two directions and two target widths) conditions. It was computed by the following formula:

$$\text{Remembered width} = \frac{\sum_{i=1}^{n} c_i * w_i}{c_{total}}$$

with n = the number of comparison stimuli, w_i = the width of comparison i, c_i = the number of ‘equal’ responses to comparison i, and c_{total} = the total number of ‘equal’ responses. Thus, for each condition, we summed the products of the proportion ‘equal’ responses and the width of the comparison pliers, and subsequently divided this by the summed proportions of ‘equal’ responses in that particular condition. We performed a repeated measures ANOVA on these remembered widths with direction and target width as within subject factors and task order as a between subject factor. Forward displacement would be consistent with a larger remembered width for opening than for closing pliers. In order to see whether the remembered width differed from the actual target width, we performed one-sample *t*-test on the average remembered width minus the target width for each participant.

We took .05 as the level of significance. All effects with a $p < .10$ will be mentioned. Mean values of the dependent variables will be presented as ± the standard error of the mean (SEM).

Grasping task

The average maximum grip aperture was 93 ± 3.82 mm. The participants' averages ranged between 67 mm and 117 mm.

Figure 3A shows the maximum grip aperture for each target width and direction. There was a main effect of target width on maximum grip aperture, $F(1, 12) = 46.54$, $p < .01$. Participants opened their fingers on average 3.15 ± 0.47 mm wider when they grasped pliers with a target width of 47 mm than pliers with a target width of 37 mm. This corresponds to a slope of 0.315 ± 0.047 for the linear fit which relates maximum grip aperture to object size. In other grasping studies, in which physical objects are grasped, this slope is usually larger (on average 0.8; Smeets & Brenner, 1999). Our small slope is probably due to participants' uncertainty about the object's size and distance as there is less information available about these properties in grasping with robot arms in a virtual environment, compared to grasping physical objects in a natural environment. There may also be a difference between grasping rigid objects (other studies) and grasping force fields (our study).

The maximum grip aperture also depended on direction of change, $F(1, 12) = 7.13$, $p = .02$. Figure 3B plots the direction effect ± SEM for each target width. The direction effect is computed by subtracting the maximum grip aperture for closing pliers from the maximum grip aperture for opening pliers (so that a positive value reflects forward displacement). On average, participants opened their fingers 1.32 ± 0.47 mm wider when the pliers had been opening than when they had been closing. Thus, we found forward displacement in grasping.

Note that for grasping, we cannot say anything about the absolute width subjects were aiming for, or what the 'correct' maximum grip aperture should have been. However, we can estimate how much larger the width was that they were aiming for when the pliers had been opening compared to when they had been closing. This is not just the direction effect of 1.32 mm; we have to relate the direction effect to the effect that an actual width difference has on maximum grip aperture. As mentioned before, a 10 mm larger target width causes the subjects to open their fingers on average 3.15 mm wider (the effect of target width). As maximum grip aperture scales linearly with object size, a difference in maximum grip aperture of 1.32 mm is thus equivalent to the effect of an actual width difference of $1.32 / 0.315 = 4.18$ mm (i.e., the direction effect divided by the slope that relates maximum grip aperture to target width). In this way, we correct the direction effect for the effect of physical width on maximum grip aperture. We express it as the physical width difference that would have caused the same difference in maximum grip aperture as the observed direction effect.

It is not trivial to estimate the reliability of this corrected direction effect. In order to do this, we have to take the variability of both the measured direction effect and the measured slope into account. Recently, Franz (2005, see also Franz, Fahle, Bülthoff, & Gegenfurtner, 2001b) described a statistical method, based on Fieller's theorem (Fieller, 1932, 1954), especially for handling this problem. It assumes that the subjects' size effects and direction effects are normally distributed. Using this method, we estimated the 95% confidence limits of the corrected direction effect to be 0.81 and 9.47 mm (Figure 3E, left bar).

There were no effects of order (whether subjects performed the visual task first or the grasping) and no interactions between any of the independent variables on maximum grip aperture (all $p > .10$).

Visual task

Figure 3C shows the remembered width for each target width and direction of change. There was a clear effect of target width on remembered width, $F(1, 12) = 3632.09$, $p < .01$. On average, participants remembered the target width of 47 mm as being 10.02 ± 0.16 mm larger than the target width of 37 mm. This corresponds to a slope of 1.002 ± 0.016 for the linear fit which relates remembered width to object width.

Forward displacement would be consistent with a larger remembered target width when the pliers had been opening than when they had been closing. Although the remembered width tended to be 0.39 ± 0.32 mm larger for opening pliers than for the closing pliers, the repeated measures ANOVA indicated that this was not significant no main effect of direction on remembered width, $F(1, 12) = 2.74$, $p = .12$. Figure 3D shows the direction effect (the remembered width for opening pliers minus the remembered width for closing pliers) for the two target widths.

Analogous to the correction of the direction effect in the grasping data, we corrected the direction effect for the effect of physical width in the visual data. This was 0.39 / 1.002 = 0.39 mm with 95% confidence limits of −0.30 and 1.06 mm (Figure 3E, right bar).

There was a significant interaction between direction and order on remembered width, $F(1, 12) = 11.29$, $p = .01$. For participants who did the visual task first, the remembered width was on average 1.18 ± 0.25 mm smaller for closing than for opening pliers, whereas for participants who did the grasping first, the remembered width was 0.40 ± 0.31 mm larger for closing than for opening pliers. Thus, participants who performed the visual task first showed a stronger forward displacement than participants who did the grasping first. While this interaction could be an indication of an interesting interplay between perception and action, two other studies in our lab using very similar experimental designs failed to show such a dependency (Franz, Bülthoff, Fahle, & Thornton, 2001a;

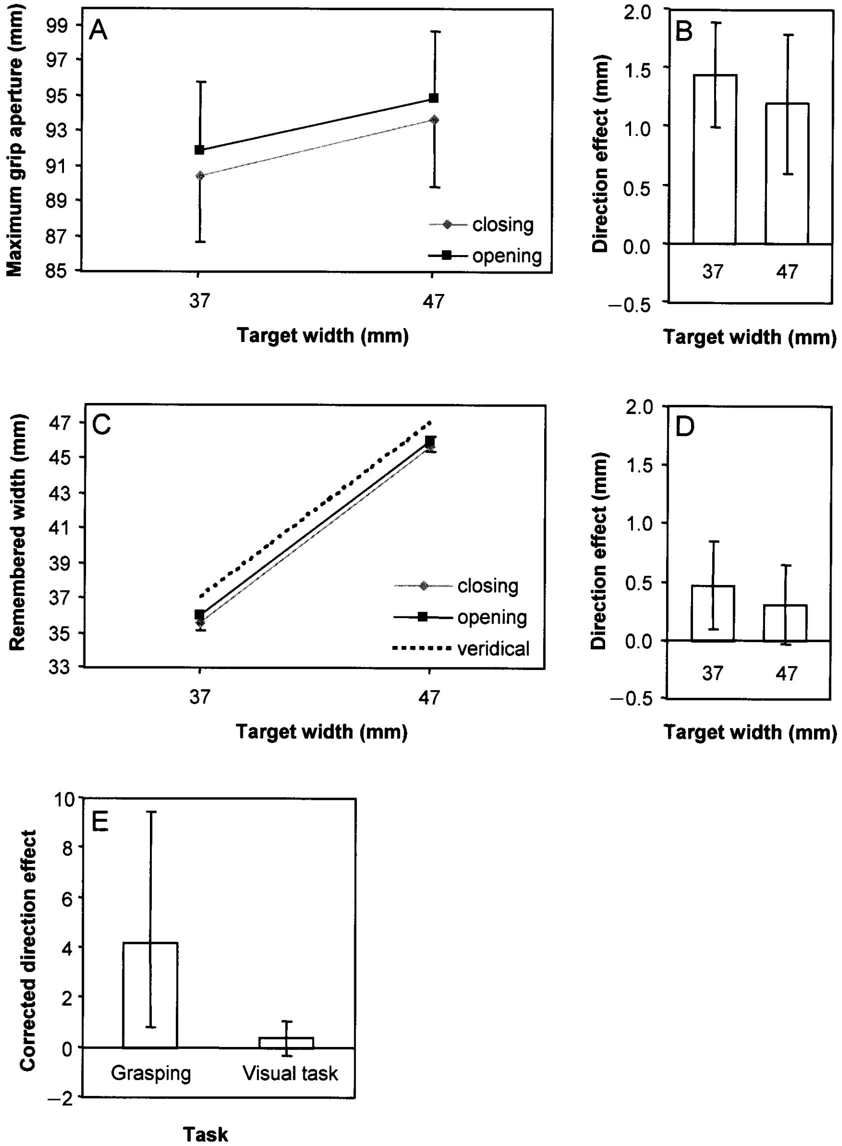

Figure 3. The main results for grasping (AB), the visual task (CD) and their comparison (E). Error bars represent the standard error of the mean (some of the error bars are smaller than the symbols) in Figure A through D. Error bars in Figure E represent the 95% confidence limits (not equal for upward and downward direction). **A.** Maximum grip aperture as a function of target width and direction. **B.** Direction effect (maximum grip aperture for opening pliers minus that for closing pliers) for each target width. **C.** Remembered target width as a function of target width and direction. **D.** Direction effect (remembered width for opening pliers minus that for closing pliers) for each target width. **E.** The corrected direction effects (across the two target sizes) for grasping and the visual task.

Brouwer, Franz, & Thornton, 2004), suggesting instead that the current pattern of data simply reflects random group variability. In any event, the overall pattern of data showed no reliable influence of the implied history of the object on visual judgments.

In contrast to the grasping responses, we can compare the visual responses against the veridical. All data points in Figure 3C are below the dashed line that indicates veridical performance. This means that, although participants remembered the target width of the pliers correctly relative to one another (a slope close to 1), there was a bias of perceiving them as more closed than they actually were in all conditions. On average, the remembered width was 1.24 ± 0.21 mm smaller than the actual width. A one sample *t*-test on remembered width minus physical target width indicated that this difference was significantly different from zero, $t(13) = -5.94$, $p < .01$.

Link between grasping and the visual task

If the same visual information or mechanism is used in both the grasping and the visual task, we would expect to see a correlation between the degree of forward displacement in the two tasks. Figure 4 plots for each participant the direction effect for the visual task (the difference between opening and closing in remembered width, plotted on the horizontal axis) and grasping (the difference between opening and closing in maximum grip aperture, plotted on the vertical

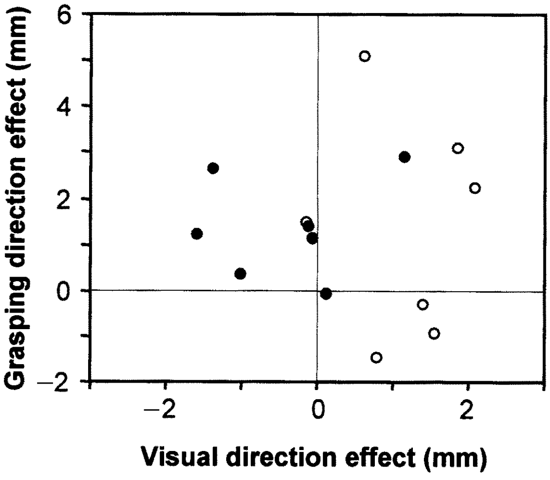

Figure 4. The effect of direction in grasping plotted against the effect of direction in the visual task. A positive value means that the effect is in the direction of anticipation. The open dots represent data of participants who did the visual task first and the filled dots represent data of participants who did the grasping task first.

axis). A positive value means that the remembered width, or the maximum grip aperture, is larger in the opening than in the closing condition (that is, forward displacement). Clearly, there is no correlation ($R^2 < .01$).

DISCUSSION

This study provides clear evidence that participants adapt their grasping movements to the visual history of an object. That is, although we asked participants to grasp the *third* stimulus, and even provided accurate haptic feedback, they still anticipated the implied opening or closing of the pliers, adjusting their maximum grip aperture accordingly. We have thus shown a grasping equivalent of the classic forward displacement in perception.

In contrast to grasping, the visual task did not show a clear effect of direction of motion. There have been a number of studies which also showed a lack of visual forward displacement. These involve objects changing brightness (Brehaut & Tipper, 1996), transformations involving natural facial expressions (Thornton & Freyd, 1998), growing and shrinking cubes (Franz et al., 2001a) and morphs between familiar and novel objects (Thornton, Vuong, Knappmeyer, & Bülthoff, 2002). A striking difference between the stimuli that induce forward displacement and those that do not is that the former all involve motion (in the sense of changing position) whereas the latter are better described as involving transformation. Our opening and closing pliers can also be considered as a more or less transforming object. In a more recent experiment (Brouwer, et al., 2004) we purposely manipulated whether a stimulus was interpreted as two separately translating spheres or a single transforming object. To obtain the transforming object, we connected the spheres by adding a bar, resulting in a pair of dumbbells. In line with our hypothesis, forward displacement was weaker for the transforming dumbbells than the translating spheres. Two other factors that additionally may have contributed to the lack of clear forward displacement in the current visual task are the fact that we used random rather than blocked presentations of transformation direction (opening and closing) and that the pliers were lying on a squared background which provided a structured background. These factors have both been shown to reduce forward displacement under some circumstances (Kerzel, 2002, and Gray & Thornton, 2001, respectively).

An effect that was more prominent in the visual task than forward displacement, was that the distance between the pliers' handles was remembered as smaller than it actually was (all data points below the dashed line in Figure 3C). Similar phenomena are well known in psychophysical research. If subjects are asked to match a comparison object to a target object presented in an illusory context, they generally do not only set the comparison object to be larger in size in the one illusory context compared to the other, but they also set the comparison object to be on average smaller in size than the target object (Franz et al., 2000; Franz et al., 2001b; Franz, Bülthoff, & Fahle, 2003; Jordan & Haleblian, 1988). Typically, the latter effect is interpreted as a constant bias which is independent of the illusion effect. Coren and Girgus (1978) followed Wuersten (1947) by calling this bias 'error of the standard'. A possibly related phenomenon is boundary extension (Intraub, 1997). Boundary extension refers to the tendency for subjects to remember a scene as if the limits of view have been extended outward. This is equivalent to remembering the objects in the scene as smaller, or being further away, than they actually were. The distance between the handles of our pliers may have been susceptible to boundary extension, especially considering that our stimuli were photographs of pliers lying on a surface (see Gottesman & Intraub, 2002). Consistent with this, Hubbard and Blessum (2001) found that angular shapes were remembered as being more closed than they actually were.

The pattern of visual data that we found could in principle be described as a forward displacement for the pliers that have been closing, and, for whatever reason, a backward displacement for the pliers that have been opening. However, considering the apparent prevalence of a lack of forward displacement and remembering a stimulus as smaller than it actually was, we think our findings are more elegantly described as a combination of these two effects. Our recent experiment with the spheres and dumbbells (Brouwer et al., 2004) provided more direct evidence for this. In this study, we not only presented spheres separated by a decreasing or increasing distance, but also static ones. Subjects judged the distance between the static spheres as shorter than it actually was, and the judged distance for the static stimulus was in between those for the increasing and decreasing distance. Similarly, Hubbard (1995b) found evidence for both an effect of forward displacement and boundary extension in judging the final distance of approaching, receding and static squares. Thus, also in the present study, an effect like boundary extension (which was strong) and forward displacement (which was weak), may have jointly determined the remembered percept.

Although forward displacement was unclear in the visual task, it was strong in grasping. By expressing the effect of direction on maximum grip aperture as the physical difference in width that would have caused the observed direction effect, we could more directly compare the size of the forward displacement between the visual and grasping task. Forward displacement in grasping appeared to be much stronger than in the visual task (although the 95% confidence intervals just overlapped, see Figure 3E). A stronger forward displacement for action than for perception is consistent with findings by Franz et al. (2001a), Kerzel (2003) and Motes et al. (2005). One explanation of different direction effects in the two tasks could be that anticipation is much more important if we perform an action on an object than if we only observe it, leading to a stronger forward displacement in grasping than in the visual task. Regardless of the specific reason for it, our findings argue against a simple model in which one form of anticipation, arising from a single, common source, serves both vision and action. Additional support for this is the lack of correlation between the two direction effects in the data of individual observers. In our other study (Brouwer et al., 2004), subjects not only judged but also grasped the dumbbells and spheres. Again, we found no correlation between the two direction effects. Additionally, the effect of the type of stimulus or stimulus change (translating spheres versus transforming dumbbells) was opposite in visually judging than in grasping; spheres giving rise to a stronger forward displacement than dumbbells in visually judging, whereas spheres gave rise to a weaker forward displacement than dumbbells in grasping. This is another kind of evidence arguing against the use of one mechanism or one source of information for anticipation in both vision and action.

In sum, the current study provides clear evidence that the direction of visually implied change affects grasping. The precise nature of this anticipation and its relationship with previously reported visual forward displacement remains the focus of future research.

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