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RESEARCH NOTE

Grasping the Müller–Lyer illusion: not a change in perceived length

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Abstract Peak grip aperture has often been used to quantify the influence of illusions on judgments of size for action. However, a larger peak grip aperture need not mean that the object looks larger. It could also mean that it was grasped more carefully. These two possibilities can be distinguished on the basis of the velocity of grip closure just before contact. We let people grasp a bar that was placed on the shaft of a Müller–Lyer figure. The Müller–Lyer figure influenced the peak grip aperture. It did not influence the velocity of grip closure in the way that one would expect if size were misperceived. Thus there is no reason to assume that the perceived size guides the way that we reach and grasp an object.

Introduction

There is a long debate in the literature about the functions of the two streams of visual information processing (e.g. Trevarthen 1968; Mishkin et al. 1983; Goodale and Milner 1992; Glover 2004). Within this debate the emphasis has gradually shifted from a distinction between ambient and focal vision via one between vision for recognition and localisation to one between visual processing for perception and for action. Within tests of the latter distinction, the dominant paradigms have gradually changed from experiments comparing the processing of position and motion for perception and goal-directed arm movements (Bridgeman et al. 1979; Smeets and Brenner 1995) to experiments comparing the processing of size for perception and grasping (Aglioti et al. 1995; Franz et al. 2001).

The original finding that illusions affect perception much more than they do peak grip aperture (Aglioti et al. 1995) has been reproduced several times (though not in all attempts; for a review see Carey 2001), but the controversy about the interpretation of the results has not been resolved (Franz 2001; Smeets et al. 2002). The main argument against interpreting the original finding as evidence for a dissociation between perception and action is that not finding the influence on peak grip aperture that one expects on the basis of the perceived size could just mean that the task that was used to determine the perceived size was inadequate (Vishton et al. 1999; Franz 2003). With a slightly modified perceptual task, illusions can influence the estimated size to the same extent as they do the peak grip aperture (Pavani et al. 1999; Franz 2001; Franz et al. 2001). However, this argument can also be reversed: by looking for tasks that give comparable results one may be equating unrelated effects.

It is evident that size is not the only factor that influences the peak grip aperture. If the grasping movement needs to be more precise, peak grip aperture will be larger and will occur earlier in the movement (Smeets and Brenner 1999). Obstacles near the target object can lead to a decrease in peak grip aperture (Mon-Williams et al. 2001). Figures that give rise to size illusions can also have effects on grasping that are not caused by

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the misjudged size but by other aspects of the figures (de Grave et al. 2005). Thus an illusion that leads to a larger grip aperture might do so through its influence on the perceived size (illusory size hypothesis), but it could also do so because parts of the illusion are regarded as obstacles (Haffenden et al. 2001) or because the movement is judged to require more accuracy (illusory accuracy hypothesis). Conversely, misperceiving the size need not affect grasping at all, because human grasping may not rely on judgements of size (Brenner and Smeets 1996; Smeets and Brenner 1999) or may rely on separate processing of size information that is not susceptible to illusions (Aglioti et al. 1995; Haffenden and Goodale 1998).

Since we cannot distinguish between effects on peak grip aperture that are caused by illusory changes in judged size and ones caused by other changes (such as changes in judgments of the required accuracy) by only looking at illusions' effects on peak grip aperture, we must also look at other measures. For instance, we could look at the movement time. Illusions change the apparent size of an object, without changing its physical size. If the positions at which the digits are expected to contact the object do not match the physical size (illusory size hypothesis), contact will be made at an unexpected moment. If the object is perceived to be smaller than it really is, the fingers will hit the object earlier than expected, so the movement time is unexpectedly decreased. The relative timing of the peak grip aperture will therefore be late. Conversely, if the object is perceived to be larger than it really is, the fingers will have to close further than planned to reach the object. The movement time will increase and the relative timing of the peak grip aperture will therefore be earlier.

Unfortunately, finding the above-mentioned relationships between the influence of the illusion on peak grip aperture, movement time and timing of peak grip aperture cannot confirm that the effects are caused by misperceiving the size, because changing judgements of the required accuracy predicts the same relationships. If the grip is judged to require a higher accuracy the movement is slower (longer movement time), and the grip opens further and earlier (reviewed by Smeets and Brenner 1999)

The two hypotheses do differ in their predictions for the final velocity of grip closure. According to the illusory size hypothesis, the velocity near contact will strongly depend on the configuration of the figure. For an object that looks smaller than it is, the closure velocity will abruptly drop to zero at the unexpectedly early contact with the object. For an object that looks larger than it is, there will be a long low-velocity phase after the expected moment of contact. The illusory size hypothesis therefore predicts two very different patterns of final grip closure. According to the illusory accuracy hypothesis, the final velocity will always gradually decline towards zero at contact, but the speed of the deceleration might depend on the configuration (in accordance with the changes in peak grip aperture and movement time; we will quantify these predictions in the Model predictions section of the Methods). Thus the velocity of grip closure just before contact may enable us to distinguish between the two hypotheses.

We let people grasp a bar that was superimposed on the shaft of a Müller–Lyer figure. There were either inward pointing or outward pointing fins at each end of the figure. The shaft in the fins-out configuration is perceived to be longer than the shaft in the fins-in configuration. Thus, according to the illusory size hypothesis one expects a larger peak grip aperture when grasping the fins-out configuration. If the fins influence judgements of the required accuracy because they are regarded as obstacles, only the fins in the fins-out configuration will have an effect because they are close to the digits' path. So, also the illusory accuracy hypothesis predicts a larger peak grip aperture for the fins-out configuration than for the fins-in configuration. In both cases, the fins increase the size of the apparent contact surface (relative to a no fins situation), which might reduce the judged accuracy. Several studies have shown that the Müller–Lyer figure influences grasping movements in accordance with both these hypotheses, (Daprati and Gentilucci 1997; Otto-de Haart et al. 1999; Westwood et al. 2000a, 2001; Franz et al. 2001).

The effect of the illusion on peak grip aperture is known to be larger if the movements are made without direct visual information (Westwood et al. 2000b; Heath et al. 2005, 2006), but since removing visual information forces subjects to abandon their normal visuo-motor control strategies we decided to perform the experiment under full vision. To prevent our subjects from making stereotypical movements we let them start their grasping movements at two different positions, and move towards bars of three different lengths. We chose starting positions in front of and to the right side of the figure, so that the arm would not occlude the figure during the movement (our subjects were all right handed).

Methods

Subjects

Twelve subjects volunteered to take part in the study after being informed about what they would be required to do. They were all right handed. This study is part of an ongoing research program that has been approved by the local ethics committee.

Set-up

Subjects had to grasp bars (60, 65 or 70 mm long, 5 mm wide, 3 mm high) that were placed on a projection screen. The bars were placed in such a way that their height was hardly noticeable (near-orthogonal viewing), but the subjects could clearly see that the bars were real objects. Stimuli were projected from below the screen. The resolution of the projected image was $1{,}024 \times 768$ pixels; with 1 pixel corresponding with about 0.4 mm. IREDs were taped to the nails of the subject's right index finger and thumb. Positions of these IREDs were measured with a frequency of 250 Hz with an Optotrak 3020 motion recording system (resolution 0.01 mm).

Stimulus

The projected stimulus consisted of a white background with a black Müller–Lyer figure and a black dot indicating the starting position (Fig. 1a). The vertical shaft of the projected image exactly matched the size of the real bar. The length of the fins was 19.5 mm. The angles between the fins and the shaft were 30° or 150°. This resulted in two configurations of the Müller–Lyer illusion: the fins-in and the fins-out configuration. The black dot indicating the starting position had a diameter of 5 mm and could either appear 15 mm beneath the proximal end of the shaft or to the right of the centre of the Müller–Lyer figure. In the latter case, the distance between the centre of the Müller–Lyer figure and the starting position was equal to the length of the shaft of the Müller–Lyer figure.

Procedure

Subjects stood in front of the screen, with their midline aligned with the midline of the screen (Fig. 1b). Before each trial, the starting position was projected onto the screen. Subjects put their right hand at the starting point with the tip of their index finger and thumb touching each other. Then subjects closed their eyes, after which the stimulus was projected and the experimenter placed the bar exactly on the shaft of the projected Müller–Lyer figure. The experimenter then gave a verbal signal, following which the subject opened his or her eyes, grasped the bar, and placed it at the bottom of the screen. This procedure was repeated for every trial. The experiment consisted of 12 conditions (3 bar lengths, 2 configurations and 2 starting positions) that were each repeated 10 times, resulting in 120 trials per subject, in random order.

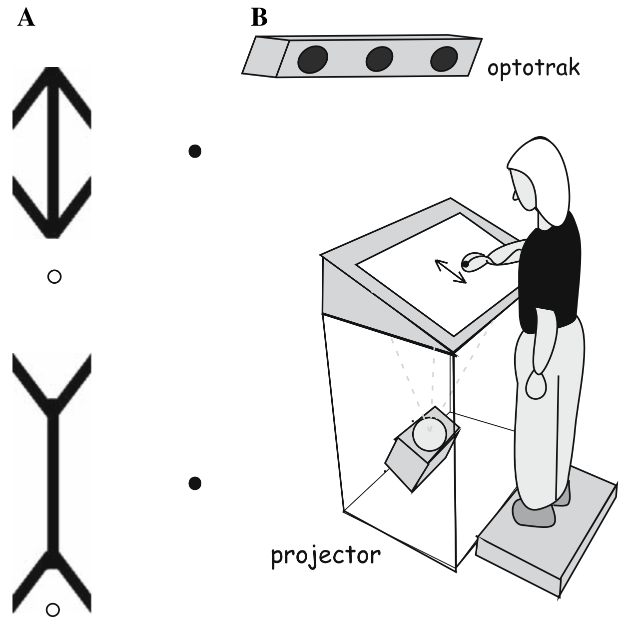

Fig. 1 **a** Stimuli used in the experiment. The *upper panel* shows the fins-in configuration of the Müller–Lyer illusion (the shaft looks smaller); the *lower panel* shows the fins-out configuration (the shaft looks larger). The *dots* represent the starting positions of the hand, either at the bottom of the Müller–Lyer figure (*open*) or at the right side of the figure (*filled*). **b** Subjects stood behind a big, slanted screen onto which the stimuli were projected from below. Positions of the index finger and thumb were measured by an *Optotrak* system

Data analysis

Grip aperture was defined as the distance between index finger and thumb. Velocities were computed from a local fit to seven position samples of the IREDs for each frame (for the exact method see Biegstraaten et al. 2003). Because of the rather small movement amplitude of the thumb when the starting position was below the figure, the beginning and end of the grasping movement were defined on the basis of the tangential velocity of the index finger. The onset of the movement was defined as the last frame before peak velocity in which the velocity was smaller than that on the preceding frame. The offset was defined as the first frame after peak velocity in which the velocity was smaller than that on the following frame (for a discussion about determining movement onsets and offsets also see Biegstraaten et al. 2003). The movement time was calculated as the time between onset and offset of the movement.

Statistics

Statistical tests were conducted across subjects. Data were analysed with repeated measures ANOVA's with the factors bar length (60, 65, 70 mm), configuration (inward pointing fins, outward pointing fins) and starting position (below, right). Dependent variables were: peak grip aperture, movement time and percentage time to peak grip aperture. Values are presented as the mean ± standard errors between subjects. A significance level of $\alpha = 0.05$ was used for all statistical analyses.

Model predictions

In order to get a more quantitative idea about the differences between the predictions of the illusory size hypothesis and of the illusory accuracy hypothesis, we modelled the influence of the stimulus on smooth grasping movements following each of these hypotheses with the digit model of Smeets and Brenner (1999). This model generates trajectories for the digits' movements towards the bar for given initial and final positions, movement time and approach parameter (a_p the parameter that captures the required accuracy). The two hypotheses differ in the way in which the model achieves changes in the maximum grip aperture; for the illusory size hypothesis they are achieved by changing the anticipated final position, whereas for the illusory accuracy hypothesis they are achieved by changing the approach parameter. Values for some of the parameters were based on the experimental results that we will present in the next section.

We used a 65 mm bar and a movement time of 715 ms (the observed overall average movement time). We chose the value for a_p that would give us about the same peak grip aperture as was observed. The average observed peak distance between the markers was 95 mm. This corresponds to a peak grip aperture of about 80 mm due to the fact that the markers are attached to the nails rather than the tips of the digits. This peak grip aperture is obtained for $a_p = 0.82$ m. We used this simulated movement as our baseline for modelling the effect of the illusion as predicted by the two hypotheses. The illusion is modelled as a change in bar-length for the illusory size hypothesis, and as a change in approach parameter for the illusory accuracy hypothesis. In the rest of the section we explain the further choices that we made.

According to the illusory size hypothesis, the influence of the fins-in configuration is a result of the bar being perceived to be smaller than it physically is. The expected difference in peak grip aperture between the two configurations is about 3 mm (Daprati and Gentilucci 1997; Otto-de Haart et al. 1999; Westwood et al. 2000a, b, 2001). Westwood et al. (2000a) showed that the peak grip aperture in a neutral configuration (crosses instead of fins) is more or less in between that in the other two configurations. Therefore, we assume that each configuration has an effect of 1.5 mm. We modelled this by simulating a movement towards a 2-mm smaller target bar with the same a_p and (planned) movement time as in the baseline. We chose 2 mm because movements towards a 2-mm smaller target are expected to have an approximately 1.5 mm smaller maximal grip aperture (Smeets and Brenner 1999). We refer to the value for the movement time as the planned movement time because the movement is actually stopped by the physical bar before this time (because the bar was larger than anticipated). The moment at which this happens is the moment at which the grip aperture of the simulated movement reaches the size of the bar. At this moment the closure velocity abruptly drops to zero. This is about 40 ms before the end of the planned movement, so if the misperception is not noticed until the actual moment of contact then this alone already predicts a very large difference in movement time. The solid curve in the left inset of Fig. 2a shows the velocity of simulated grip closure during the last 60 ms before contact. The fingers hit the bar just after the peak closure velocity.

For the fins-out configuration, the illusory size hypothesis assumes that the bar is perceived to be larger than it physically is. We modelled this by simulating a movement towards a 2-mm larger target bar with the same a_p and (planned) movement time as in the baseline. In this case the fingers have not yet reached the bar at the planned movement time (because the bar is smaller than anticipated). The grip must close further for the fingers to reach the bar. It seems reasonable to assume that the grip continues to close at a more or less constant modest speed until the digits make contact with the bar, but we cannot derive the moment of contact from the model in the way that we could for the fins-in configuration. The dashed curve in the left inset of Fig. 2a shows what the final velocity of grip closure would be if the grip closes at the (constant) speed that will prolong the movement time by the same amount as it is shortened by colliding with the object in the fins-in condition. This is an arbitrarily choice, but since we expect the velocity of grip closure to decrease towards the end of the movement it is unlikely that the movement time will change by less than this (assuming that the illusion itself is symmetrical with respect to a bar without any fins). An even larger increase in movement time would result in a lower grip closure velocity. Subjects might rely to some extent on contact with the object's surfaces to help stop

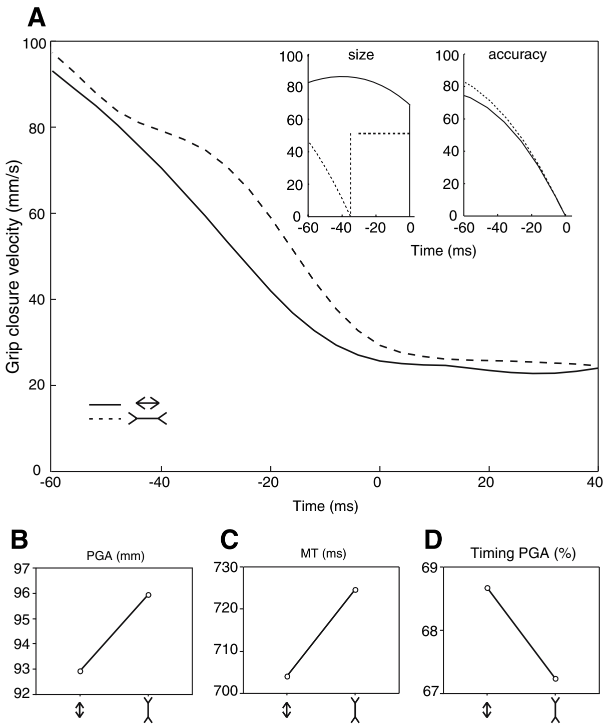

Fig. 2 **a** The average velocity of grip closure near movement offset. *Dashed lines* represent movements towards the fins-out configuration of the Müller–Lyer figure. *Solid lines* represent movements towards the fins-in configuration. Each line is the average over all subjects, bar lengths and starting positions. Time is relative to movement offset. The insets show the predictions for the illusory size hypothesis (*left panel*) and the illusory accuracy hypothesis (*right panel*). The hypotheses predict similar changes in peak grip aperture and its timing (not shown), but they differ in their prediction for the velocity of the grip closure near contact. **b**–**d** The average peak grip aperture, movement time and time to peak grip aperture (as a proportion of the total movement time) for the two configurations of the Müller–Lyer illusion

the digits, so that the intended movement does not end with a velocity of zero. Subjects might also adjust the movement on the basis of relative positions as the digits come close to the bar. These strategies could smoothen the movements and reduce the differences in movement time, but a smaller maximal grip opening (smaller anticipated size) will still be associated with a higher velocity of final grip closure.

According to the illusory accuracy hypothesis, the fins influence judgements of the required accuracy, and thereby the movement time and the approach parameter. The right inset of Fig. 2a shows what the final velocity of grip closure would be if the movement times changed by the same 40 ms that we predicted for the illusory size hypothesis, and the approach parameters had the values that were needed to obtain a 1.5 mm larger peak grip aperture for the fins-out configuration and a 1.5 mm smaller peak aperture for the fins-in configuration than in the baseline. The final positions were the same for both configurations. The model predicts that just before contact the closing velocity of the fingers is slightly higher in the fins-out configuration. This means that the increase in grip closure velocity in the fins-out configuration as a result of the larger maximum grip aperture (i.e. larger value of a_p) is stronger than the decrease in grip closure velocity as a result of the movement being slower.

Results

Figure 2a shows the average velocity of grip closure around the moment that the bar is grasped (time zero is movement offset). There was a clear gradual decrease in velocity before contact with the bar. After contact with the bar, the grip continued to close at a constant low rate, because the thumb reached the object later than the index finger on some trials and because the skin compresses a bit as the grip force increases. This pattern was more or less the same for the two configurations of the Müller–Lyer illusion. The rate at which the grip closed on the bar appeared to be faster just before contact when the bar looked larger (fins-out configuration; dashed line), which is the opposite of what the illusory size hypothesis predicts (see inset), even if we smooth the predictions. This pattern is consistent with the illusory accuracy hypothesis.

The fact that the final velocity of grip closure was not larger for the fins-in configuration cannot be explained by the illusory figure itself being ineffective: the difference in peak grip aperture between the fins-out configuration and the fins-in configuration was 3.6 mm ($P = 0.0017$; Fig. 2b). This is even slightly larger than the effects found in previous studies using the Müller–Lyer illusion (Daprati and Gentilucci 1997; Otto-de Haart et al. 1999; Westwood et al. 2000a, b, 2001). Moreover, as both hypotheses predicted, movement times were longer for the fins-out configuration (726 ± 23 ms) than for the fins-in configuration (708 ± 23 ms; $P = 0.01$; Fig. 2c) and the relative timing of peak grip aperture was earlier for the fins-out configuration than for the fins-in configuration (67 ± 0.7% and 68 ± 0.7% of the MT, respectively; $P < 0.05$; Fig. 2d). Both the starting position and bar length obviously influenced the various movement parameters, but there were no significant interactions with the configuration.

Discussion

In no way did the influence of the illusion on the final velocity of grip closure resemble what one would expect for misjudging the object's size (Fig. 2). The illusion's influence is consistent with the predictions based on the assumption that the fins change the judged required precision. The observed influence of the configuration on the movement time was smaller than we assumed in the model calculations. For the illusory size hypothesis this could only be achieved if the grip closure was faster than we predicted with the digit model. If so, this would lead to more extreme differences in the final velocity profiles between the configurations. However, we found peak velocity slightly earlier (at 68%) than the model predicted (72%), so the grip closure was slightly slower than predicted. So the small effect on movement time argues against the illusory size hypothesis. For the illusory accuracy hypothesis, a smaller difference in movement time increases the extent to which the predicted closure velocity is faster for the fins out configuration a bit. So the fact that the difference in movement time was smaller than we predicted does not change our conclusion.

In our analysis, we did not consider the possibility that the visual information that is used changes during the movement. One might argue that our results are compatible with the illusory size hypothesis, because changes in the used information during the movement could be responsible for the observed velocity profiles. For instance, subjects might gradually shift from using information that is susceptible to illusions to using information that is not (e.g. from object size to feedback about the distance between the digits and the object), as has been suggested by Glover (2004), which could also explain why full visual information reduces (rather than abolishing) the effect of the illusion on peak grip aperture. However, by modelling some of the conditions that have been used as support for a diminishing influence of illusions during actions, we have shown that it is not necessary to assume that the use of visual information changes during the movement, because influences of the illusion on certain but not on other attributes of the target predict that the effects of the illusions will diminish during the movement without any change in the information that is used (Smeets et al. 2002, 2003). Direct experimental evidence also indicates that subjects do not neglect context elements later in the movement. For instance, the flankers in the Ebbinghaus illusion have an effect on grip orientation at the moment of peak grip aperture (de Grave et al. 2005). This effect on grip orientation did not diminish at the end of the movement, but even increased after the moment of peak grip aperture, although subjects in this study had full visual information.

The illusory precision hypothesis is consistent with the results found for the Müller–Lyer illusion (this study), and can also explain the effects of the Ebbinghaus illusion on grip aperture (Smeets et al. 2003). For the Ponzo illusion, we are not aware of any reports of the misperceived size influencing grip aperture (Brenner and Smeets 1996; Jackson and Shaw 2000). The converging lines in the Ponzo illusion are generally further from the bars whose length they influence, and the lines are less obstacle-like than the fins of the Müller–Lyer illusion and the surrounding disks in the Ebbinghaus illusion, so their negligible effect on grip aperture is consistent with the illusory precision hypothesis because there is little reason to expect a change in the estimated required precision. That size illusions do not only affect grasping through their influence on the perceived size is unfortunate because it makes it more difficult to use size illusions as a tool for studying whether (and how) size judgments are used to guide human grasping (de Grave et al. 2004).

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References

Aglioti S, DeSouza JFX, Goodale MA (1995) Size–contrast illusions deceive the eye but not the hand. Curr Biol 5:679–685

Biegstraaten M, Smeets JBJ, Brenner E (2003) Impact forces cannot explain the one-target advantage in rapid aimed hand movements. Hum Mov Sci 22:365–376

Brenner E, Smeets JBJ (1996) Size illusion influences how we lift but not how we grasp an object. Exp Brain Res 111:473–476

Bridgeman B, Lewis S, Heit G, Nagle M (1979) Relation between cognitive and motor-oriented systems of visual position perception. J Exp Psychol Hum Percept Perform 5:692–700

Carey DP (2001) Do action systems resist visual illusions? Trends Cogn Sci 5:109–113

Daprati E, Gentilucci M (1997) Grasping an illusion. Neuropsychologica 35:1577–1582

Franz VH (2001) Action does not resist visual illusions. Trends Cogn Sci 5:457–459

Franz VH (2003) Manual size estimation: a neuropsychological measure of perception? Exp Brain Res 151:471–477

Franz VH, Fahle M, Bülthoff HH, Gegenfurtner KR (2001) Effects of visual illusions on grasping. J Exp Psychol Hum Percept Perform 27:1124–1144

Glover S (2004) Separate visual representations in the planning and control of action. Behav Brain Sci 27:3–24

Goodale MA, Milner AD (1992) Separate visual pathways for perception and action. Trends Neurosci 15:20–25

de Grave DDJ, Brenner E, Smeets JBJ (2004) Illusions as a tool to study the coding of pointing movements. Exp Brain Res 155:56–62

de Grave DDJ, Biegstraaten M, Smeets JBJ, Brenner E (2005) Effects of the Ebbinghaus figure on grasping are not only due to misjudged size. Exp Brain Res 163:58–64

Haffenden AM, Goodale MA (1998) The effect of pictorial illusion on prehension and perception. J Cogn Neurosci 10:122–136

Haffenden AM, Schiff KC, Goodale MA (2001) The dissociation between perception and action in the Ebbinghaus illusion: nonillusory effects of pictorial cues on grasp. Curr Biol 11:177–181
Heath M, Rival C, Neely K (2006) Visual feedback schedules influence visuomotor resistance to the Müller–Lyer figures. Exp Brain Res 168:348–356
Heath M, Rival C, Westwood DA, Neely K (2005) Time course analysis of closed- and open-loop grasping of the Müller–Lyer illusion. J Mot Behav 37:179–185
Jackson SR, Shaw A (2000) The Ponzo illusion affects grip–force but not grip–aperture scaling during prehension movements. J Exp Psychol Hum Percept Perform 26:418–423
Mishkin M, Ungerleider LG, Macko KA (1983) Object vision and spatial vision: two cortical pathways. Trends Neurosci 6:414–417
Mon-Williams M, Tresilian JR, Coppard VL, Carson RG (2001) The effect of obstacle position on reach-to-grasp movements. Exp Brain Res 137:497–501
Otto-de Haart EG, Carey DP, Milne AB (1999) More thoughts on perceiving and grasping the Müller–Lyer illusion. Neuropsychologica 37:1437–1444
Pavani F, Boscagli I, Benvenuti F, Rabuffetti M, Farne A (1999) Are perception and action affected differently by the Titchener circles illusion? Exp Brain Res 127:95–101
Smeets JBJ, Brenner E (1995) Perception and action are based on the same visual information: distinction between position and velocity. J Exp Psychol Hum Percept Perform 21:19–31
Smeets JBJ, Brenner E (1999) A new view on grasping. Motor Control 3:237–271
Smeets JBJ, Brenner E, de Grave DDJ, Cuijpers RH (2002) Illusions in action: consequences of inconsistent processing of spatial attributes. Exp Brain Res 147:135–144
Smeets JBJ, Glover S, Brenner E (2003) Modeling the time-dependent effect of the Ebbinghaus illusion on grasping. Spat Vis 16:311–324
Trevarthen CB (1968) Two mechanisms of vision in primates. Psychologische Forschung 31:299–348
Vishton P, Rea J, Nunez L, Cutting J (1999) Comparing effects of the horizontal vertical illusion on grip scaling and judgment: relative versus absolute, not perception versus action. J Exp Psychol Hum Perc Perf 25:1659–1672
Westwood DA, Chapman DC, Roy EA (2000a) Pantomimed actions may be controlled by the ventral visual stream. Exp Brain Res 130:545–548
Westwood DA, Heath M, Roy EA (2000b) The effect of a pictorial illusion on closed-loop and open-loop prehension. Exp Brain Res 134:456–463
Westwood DA, McEachern T, Roy EA (2001) Delayed grasping of a Müller–Lyer figure. Exp Brain Res 141:166–173