Research News

Action does not resist visual illusions

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Recent *TICS* articles[1,2] discussed the psychophysical evidence in favor of Goodale and Milner's action vs. perception hypothesis[3]. Carey argued that most of the studies investigating the effects of visual illusions on grasping can be reconciled with the notion that the action system resists visual illusions[1]. Bruno suggested a new interpretation of the action vs. perception hypothesis in order to incorporate most of the empirical findings[2]. Here, I argue that action does not resist visual illusions. Even more, the effects on the motor system seem to be comparable to the effects on the perceptual system. This challenges the action vs. perception hypothesis in its current form.

Table 1 summarizes the studies that have investigated the effects of visual illusions on grasping[4–17]. It can be seen that a number of studies found significant effects of visual illusions on grasping. Other studies found effects that were close to being significant (the non-significant results might partially be the consequence of relatively small sample sizes). Only one study found a negative (i.e. reversed) influence on grasping[11]. If it were true that grasping resists visual illusions then the pattern of results should be much more balanced, with fewer studies finding significant effects and more finding negative effects.

One might argue that *small* effects of visual illusions on grasping can easily be reconciled with an action–perception dissociation. Some authors suggested that the effects might be caused by some partial involvement of the ventral (perceptual) stream[1,4], or even by totally different mechanisms from the perceptual illusion[1,8,18,19]. This conjecture raises a methodological problem because we have to assume that (according to the action vs. perception hypothesis) the motor system is *less* affected by visual illusions than perception. That is, it is no longer sufficient to ask whether grasping is affected by visual illusions at all, but we have to compare the *size* of the motor effects with the *size* of the perceptual effects*. In the following sections I will discuss this comparison between the size of the perceptual illusion and motor illusion with the data available in Table 1.

Standard perceptual measures provide no evidence for a smaller motor illusion

The perceptual effects of visual illusions have been assessed in different ways. In Table 1, I distinguish between standard perceptual measures and non-standard perceptual measures. Standard perceptual measures are usually used in the investigation of visual illusions. For example, participants adjust the size of a comparison stimulus to match the size of a target stimulus.

Aglioti *et al.* (Ref. 4, and replicated in Refs 5,9) found that the Titchener/Ebbinghaus illusion affected standard perceptual measures more than grasping. However, we showed that in the Aglioti paradigm the perceptual task and the motor task are not well matched[7] (see Fig. 1). This selectively increases the size of the perceptual illusion (see results in red type in Table 1: the perceptual effects of all studies that used the Aglioti paradigm). The studies that avoided this problem found a very good match between perceptual and motor effects[6,7].

The way we matched perceptual task and motor task seems, however, to have one drawback: it decreases the size of the perceptual illusion[1,20]. Nevertheless, this is not necessarily a problem for my argument because it should be *harder* to find an effect of the illusion on the motor system if the perceptual illusion is smaller. In other words, if you wanted to show some small, residual illusion effect that leaks from the ventral stream (perception) to the dorsal stream (action) you would be well-advised to use a *large* perceptual illusion and not a small one.

Non-standard perceptual measures show larger illusion effects than both perception and action

A number of studies used non-standard perceptual measures. Usually, participants estimated target size by opening index finger and thumb, either seeing or not seeing their hand and the stimulus during performance of the task[5,8,12–14,16]. I see two problems with these non-standard perceptual measures (see also Ref. 17). First, it is unclear whether these measures can be interpreted as perceptual measures. As Bruno pointed out[2], it is difficult to find *a priori* criteria for classifying these measures as perceptual. On the contrary, one might argue that the motor system is tapped with these tasks (for example, Vishton *et al.* used a similar task and interpreted it as a motor task[21]). This is even more the case if no visual feedback of the hand is allowed because participants have to rely on feedback from the motor system.

Second, these measures yield inconsistent results. For example, in the Haffenden and Goodale study[5], the difference between the non-standard and the standard perceptual measures was even larger than the difference between the standard perceptual measure and grasping results. Similarly, Daprati and Gentilucci found a large difference between the two non-standard perceptual measures[13].

Given this situation one might argue that there is just as much dissociation between standard perceptual measures and non-standard perceptual measures as there is between perception and grasping. Obviously, this is implausible. I think a careful investigation of the non-standard perceptual measures is needed. For example, non-standard perceptual measures should be systematically compared with standard perceptual measures, and should be tested under conditions in which they yield similar effects to the standard perceptual measures.

Is it possible to reconcile the action vs. perception hypothesis with these data?

There have been different attempts to reconcile the action vs. perception

*This has statistical consequences: we need to test not only whether grasping and perception show significant illusion effects, but also whether the *difference* between motor illusion and perceptual illusion is significant. Not all studies did test for this. See also Ref.17 for a discussion of further potential problems involved in this comparison.

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Table 1. Effects of visual illusions on perception and on grasping

Illusion	No. of subjects	Grasping	Perception (standard)	Perception (non-standard)	Experimental conditions	Ref.
Titchener/Ebbinghaus illusion						
Aglioti *et al.* (1995)	14	1.6 ± 0.4*	2.5 ± 0.2*		d,f	4
Haffenden & Goodale (1998)	18	1.0 ± 0.5 ns.	2.4 ± 0.2*	4.2 ± 1.0*	e,f/a,f	5
Pavani *et al.* (1999)	18	1.0*	0.7*		d	6
Franz *et al.* (2000)	26	1.5 ± 0.38*	1.5 ± 0.12*		e	7
Haffenden *et al.* (2001)	18	0.2 ns.		2.6*	e/a,g	8
Hanisch *et al.* (2001)	9	0.8 ± 0.6 ns.	1.5 ± 0.5*		d,f,h	9
Ponzo illusion						
Brenner & Smeets (1996)	8	0.3 ($p = 0.18$)	0.8*		d	10
Jackson & Shaw (2000)	8	–0.7 ($p = 0.07$)			d	11
Westwood *et al.* (2000)	10	0.6 ns.		2.3*	d/b	12
Müller-Lyer illusion						
Daprati & Gentilucci (1997)	8	1.0*		3.7*, 2.4*	d/b,c	13
Otto-de Haart *et al.* (1999)						14
binocular	14	1.7 ($p = 0.08$)		9.0*	d/b	
monocular	14	2.1*		12.6*	d/b	
Westwood *et al.* (2000)	6	1.0 ± 0.97 ns.		7.6 ± 1.73*	d/b	16
Westwood *et al.* (2000)	9	1.5 ± 0.98 ($p = 0.16$)			d	15
Franz *et al.* (in press)	16	3.4 ± 0.42*	2.0 ± 0.24*		e	17
Parallel lines illusion						
Franz *et al.* (in press)	26	1.2 ± 0.32*	2.3 ± 0.26*		e	17

All illusion effects are in mm ± S.E.and are the differences between an enlarging version of the illusion and a shrinking version. Grasping effects are based on maximum grip aperture. Red type indicates the use of the Aglioti paradigm[4]. Conditions investigating the effects of a time delay between stimulus presentation and response are not included. For Refs 4, 5, 9, 10, 15, 16 the values were not numerically given in the manuscripts, and were obtained from Fig. 5 (Ref. 4) and by personal communication from the authors. Ref. 23 did not report effect sizes and is not included. *$p < 0.05$
Experimental conditions: (grasping/perception-non-standard) (a) participants indicated target size by opening index finger and thumb without seeing hand and stimulus; (b) with full vision of hand and stimulus; (c) by drawing a line of the length of the target without seeing hand and paper, but seeing the stimulus; (d) full vision during grasping; (e) no vision of the hand during grasping; (f) effects calculated from only 50% of the trials (for which the calculations are comparable to the other studies); (g) only the conditions 'adjusted small' and 'traditional large' are included; (h) only the adult group is included.

hypothesis with the finding of equal motor and perceptual illusions in the Titchener/Ebbinghaus display[6,7]. Some authors have argued that the motor illusion might be generated in the motor system independently of the perceptual illusion[1,8,18,19]. This could be the case if the motor system treated the context circles as potential obstacles for the fingers and tried to avoid them. In my opinion, this is an important possibility, which should be investigated. Currently, however, I do not see strong evidence for this view because: (1) to explain the motor data in the Titchener/Ebbinghaus illusion we would have to assume that *increasing* the gap between the central element and context elements *decreases* the grasp aperture; and (2) studies that tried to demonstrate this (unusual) relationship found small and non-significant effects[18] or used non-standard perceptual measures as reference[8,18].

Carey[1] suggested that our findings[7] do not contradict the action vs. perception hypothesis, but might simply mean that the motor system takes into account only the region in close vicinity of the target (i.e. one Ebbinghaus figure) whereas the perceptual system attends to the whole visual field (i.e. both Ebbinghaus figures; see Fig. 1). This could be seen as a consequence of Milner and Goodale's notion of object-centered coding in perception versus viewer-centered coding in the motor system. However, we tested this possibility (Experiments 2 and 3 of Ref. 7) and showed, that perception does not always take into account both Titchener/Ebbinghaus figures, but only if the task requires this.

Bruno proposed[2] that the critical distinction is not between the response modes (perception vs. action), but between the frames of reference (object-centered vs. viewer-centered) which are demanded by the actual task. This view has its merits. However, it gives up the core assumption of the action vs. perception hypothesis: that the response mode determines the way visual information is processed. Thus, Bruno's suggestion abandons the action vs. perception hypothesis rather than attempting to reconcile it with the data.

In principal, I see one further possibility to reconcile the action vs. perception hypothesis with the findings of Pavani *et al.* and ourselves[6,7], which is that visual illusions could be generated relatively early, before the two systems separate. However, the Titchener/Ebbinghaus illusion seems to be dependent on higher cognitive functions[22], a finding that contradicts this possibility.

Conclusions

At first, the finding of Aglioti *et al.* that the motor system largely resisted the Titchener/Ebbinghaus illusion seemed to provide convincing evidence for the Milner and Goodale action vs. perception hypothesis. Today, this finding is in doubt and the accumulated evidence suggests that the effects of the illusion on grasping might well be similar to the effects on perception. As directions for future research, I suggest that more attention be paid to the problem of matching the task

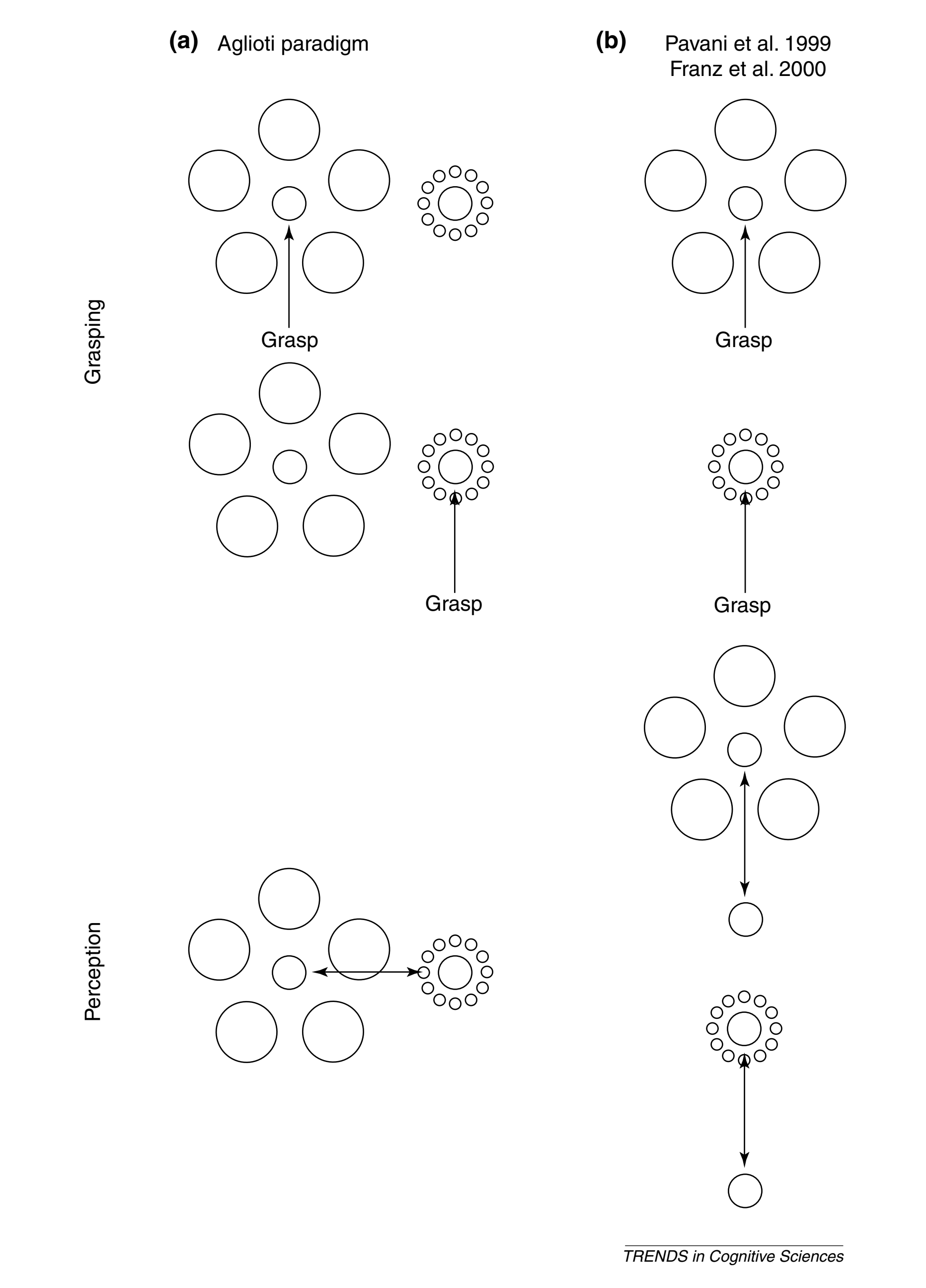

Fig. 1. Comparison of experimental designs. (a) Perceptual task and motor task of the Aglioti paradigm[4]. Two Ebbinghaus figures were presented. In the perceptual task, participants compared the sizes of the two central discs directly, whereas in the motor task they successively grasped one of the two central discs. Note the asymmetry in this procedure: in order to grasp, participants had to calculate the size of only one of the central discs at a time. In the perceptual task, however, participants had to compare the two central discs directly, both being subjected to the illusion at the same time. We showed[7] that the task demands of this direct comparison selectively increases the perceptual illusion by about 50%. (b) In the studies of Pavani *et al.*[6] and in our study[7], motor task and perceptual task were matched more closely in that only one Ebbinghaus figure was presented at a time. In the motor task participants grasped both of the central discs and in the perceptual task they compared the central disc to a neutral comparison stimulus. In these studies, no difference between the perceptual illusion and the motor illusion was found.

demands of perceptual and motor tasks and to the validity of the perceptual measures.

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