ments to a stationary target embedded in a background that moved in either the same direction as the effector or in the opposite direction. These background perturbations, which were introduced at movement initiation, produced systematic overshooting and undershooting of the target respectively. Proteau and Masson postulated that when the background was moving in the same direction, the effector was judged to be moving more slowly than it really was and the movement was not terminated as soon as it should have been (i.e., a target overshoot). When the background was moving opposite to the direction of the movement, movement velocities were judged to be greater than they really were and the movement was terminated too early (i.e., target undershoot). Once again limb control appears to be susceptible to an illusory visual context. In a related study, Brenner and Smeets (1997) demonstrated that background motion introduced after planning affected the trajectory of manual aiming movements directed at foreground targets.

The notion that the control phase of an aiming movement is affected by visual context is consistent with aiming experiments in which the size-contrast illusion has been shown to influence movement time (e.g., van Donkelaar 1999). Although we agree with Glover that movement planning is partially responsible for the movement time-target size relation (e.g., peak velocity and the time to peak velocity), experiments in which target size changes on movement initiation (e.g., Heath et al. 1998) indicate that the time after peak velocity depends more on the target size after movement onset than the size of the target prior to the initiation of the movement. Moreover, the control system is able to adjust the temporal characteristics of the movement very rapidly in order to deal with target size perturbations.

While in some of the experiments described above, the visual surround contributed to either spatial error or temporal miscalculation, under many normal circumstances, visual context may prove to be important for efficient and safe on-line control. For example, when picking a berry from a thorny bush, or removing a steak from the grill, "good planning" may not always be enough to avoid an injury. The control system needs to take into consideration objects that surround the target or unexpectedly obstruct the path to the object once the movement is already underway. Certainly our ability to intercept a moving target depends partly on the expansion-contraction of the target's image on the retina relative to other objects. Similarly, the velocity of the effector used to intercept the target object will be judged relative to the visual environment in which it moves.

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Is there a dynamic illusion effect in the motor system?

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Abstract: Glover's planning–control model is based on his finding that visual illusions exert a larger effect in early phases than in late phases of a movement. But evidence for this dynamic illusion effect is weak, because: (a) it appears difficult to replicate; (b) Glover overestimates the accuracy of his results; and (c) he seems to underestimate the illusion effect at late phases.

Scott Glover draws a plausible picture of the visuo-motor system, such that we might be tempted to follow his arguments and believe in a planning–control model of action. However, Milner and Goodale (1995) also provided a plausible account of the visuo-motor system, as have other researchers (e.g., Livingstone & Hubel 1988; Schneider 1969; Trevarthen 1968; Ungerleider & Mishkin 1982). Logically, it seems unlikely that all these theories are correct. This necessitates a careful examination of the evidence used by the researchers. Here, I argue that Glover's most important evidence, the dynamic illusion effect, is weak. In fact, the dynamic illusion effect might not exist.

Glover and Dixon (2001a; 2001b; 2002a; 2002b) found that visual illusions exert a larger effect on early phases of a movement than on late phases. However, a careful examination of the studies shows that there are a number of problems related to this finding of a dynamic illusion effect. I will explain these problems using data from one of our studies (Franz et al. 2000), which I reanalyzed to test Glover's account (Franz 2003; submitted). In this study, participants repeatedly grasped objects of different sizes while perception of size was distorted by two different levels of the Ebbinghaus illusion. The aperture between the fingers was measured at different time points in the reach-to-grasp movements. The illusion effects are shown in Figure 1a. At first sight, the illusion seems to increase over time (instead of decrease, as suggested by Glover).

However, at early time points, the grasp aperture hardly responded to *any* variation in size, even if the physical size was varied (Fig. 1b). For an evaluation of the illusion effects, we have to take into account this smaller degree of responsiveness: We have to "correct" the illusion effects for the physical size effects. Only after this correction, can we detect a dynamic decrease of the illusion effect (if it exists).

In principle, the correction could be fairly easy: At each time point, we simply divide the illusion effect by the physical size effect (cf. Franz et al. 2001; Glover & Dixon 2001a). However, we also need to estimate confidence limits for the corrected illusion effects. This is not trivial, because we have to take into account the variability of the numerator and of the denominator. Consider the case where the confidence interval of the denominator contains a zero value. In this case, the corrected illusion effect can become arbitrarily large (or small), with arbitrarily large variability.

The method Glover and Dixon used to calculate confidence limits (or standard errors) for the corrected illusion effects ignores the variability of the denominator. This underestimates the variability of the corrected illusion effects. As I have discussed in detail (Franz, submitted), this problem can be most pronounced in early phases of the movement because here the physical size effect (i.e., the denominator) is close to zero.

Figure 1c demonstrates this problem for our data: Using Glover's method, one might be tempted to interpret the large corrected effect at $t = 0\%$ as evidence for a dynamic decrease of the illusion effect. The mathematically exact method (Fieller 1954; Franz, submitted), however, clearly shows that this value is a statistical outlier (Figure 1d): The confidence limits are *infinite,* because the physical size effect is too close to zero.

Figure 1d shows that (except for the outlier at $t = 0\%$), the corrected illusion effect is surprisingly constant, contrary to Glover's proposal. Now, it may be argued that these data have a drawback: Time points occurring after the maximum grip aperture (MGA) were not included in the analysis ($t = 100\%$ corresponds to the time of the MGA). However, the reason time points beyond the MGA were not included is because the fingers are already very close to the target after the MGA, and quite often will touch the target object, which would contaminate the data. But what if the dynamic illusion effect shows up only at time points after the MGA? To test for this, we reanalyzed the data of another study (Franz et al. 2003) and made sure that the trajectories were included as long as possible, but without the fingers touching the target object. Again, we found constant illusion effects over time, without any indication of a decrease. If at all, the corrected illusion effects slightly increased over time (Franz & Scharnowski 2003).

Why, then, did Glover and Dixon find a dynamic illusion effect? A close inspection of their results shows that the decrease of the corrected illusion effect occurs mainly at very late time points,

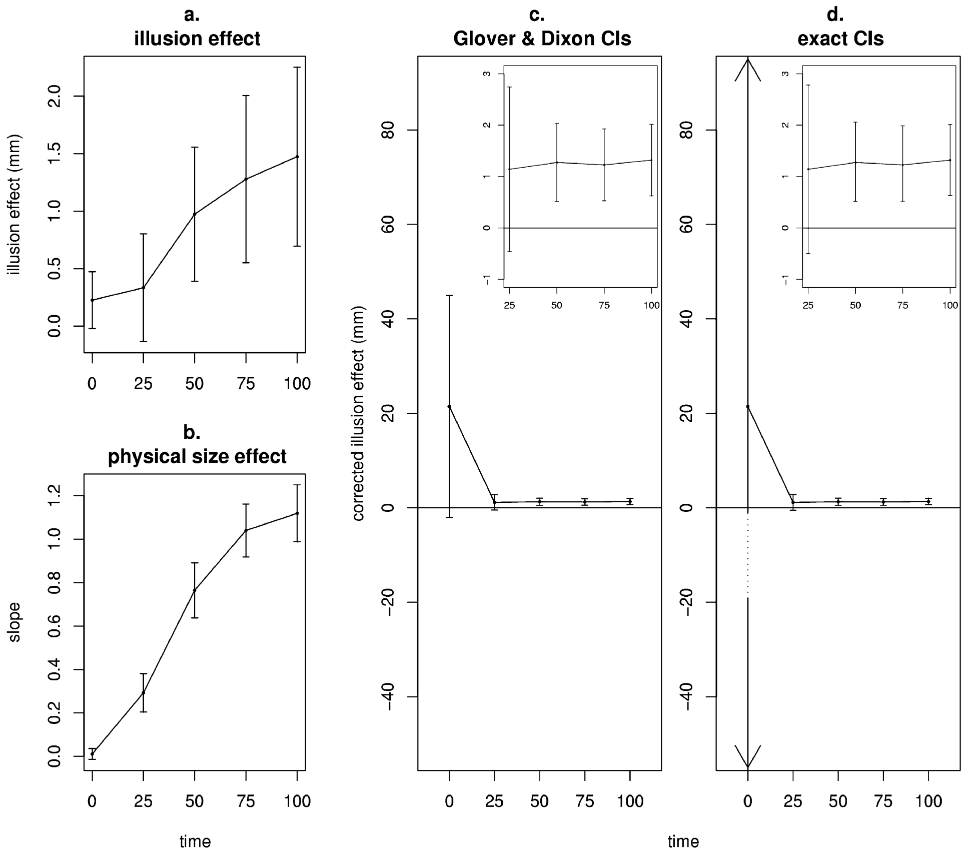

Figure 1 (Franz). Testing whether the dynamic illusion effect exists. (**1a**) Effects of the Ebbinghaus illusion on grasping as a function of time: The illusion effect is the mean difference in aperture when grasping one or the other version of the illusion. (**1b**) Effects of a physical variation of size on grasping: The physical size effect is the mean slope of the functions which relate grip aperture to physical size. (**1c**) Corrected illusion effects (i.e., illusion effects divided by physical size effects) and 95% confidence limits as calculated by Glover and Dixon's method, which ignores the variability of the physical size effects. (**1d**) Confidence limits, as calculated by the mathematically exact method (Fieller 1954; Franz, submitted): The exact method gives infinite confidence limits at $t = 0\%$; only the points on the dotted line are excluded from the confidence set, all other values are included! Data are from Franz (2003). Time is normalized, such that $t = 0\%$ corresponds to the start of the movement and $t = 100\%$ to the time of the maximum grip aperture (MGA). The insets magnify the data between t = 25% and $t = 100\%$. Error bars depict 95% confidence limits.

well beyond the time of the MGA. Most likely the fingers touched the target object at these late time points, because the trajectories were analyzed until the thumb ceased to move in a forward direction. Try it yourself: Place an object in front of you, grasp it, and move it back toward yourself (as participants did in the Glover & Dixon [2002a] study). Usually, you will have touched the object when your thumb no longer moves forward. Including time points in the analysis when participants have already touched the target object leads to a decrease of the illusion effects which is simply due to the mechanical interaction with the object and not to neuronal control processes.

In my opinion, the case of the dynamic illusion effect is not yet resolved. One possibility is that a dynamic illusion effect only shows up if participants can see their fingers during grasping. In contrast, in our studies participants could not see their fingers during grasping (note, however, that Glover and Dixon found the largest decrease in such an open loop condition). Future research should clarify this issue.

Finally, it would be interesting to know what the results of the Glover and Dixon studies would look like, if they used the mathematically exact method to calculate confidence limits and if they excluded parts of the trajectories at which participants touched the target object. Will the dynamic illusion effect survive these tests?

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Do movement planning and control represent independent modules?

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Abstract: We address three issues that might be important in evaluating the validity of the planning–control model: (1) It could be artificial to distinguish between control and planning when control involves the re-planning of a new corrective submovement that overlaps with the initial response; (2) experiments involving illusions are not totally compelling; (3) selectively implicating the superior parietal lobe in movement control and the basal ganglia in movement planning, appears questionable.

In this interesting article, Glover reviews evidence for a dichotomy between the planning and on-line control of actions. Although we