Modeling the time-dependent effect of the Ebbinghaus illusion on grasping

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Abstract—Various authors have reported a small but consistent effect of the Ebbinghaus illusion on the maximum opening of the hand during prehension. This effect has been interpreted in various ways. In the present study, we focus on the time-course of the effect of contextual elements on grasping. The analysis presented here is based on a model for the control of the digits that uses two movement parameters (the approach parameter and the intended contact positions). These two parameters are based on different spatial attributes (flanker-target distance and target-edge position). As we assume that the perception of both attributes is veridical, there is no need for on-line corrections in the model. We show that this model predicts all time-dependent effects of the Ebbinghaus display on grasping. Human behavior can show a reduction in context effects over time without assuming an underlying shift from illusory towards veridical size information.

Keywords: Prehension; motor control; illusion; size; smooth movement.

INTRODUCTION

Aglioti et al. (1995) conducted a very influential experiment on the effect of the Ebbinghaus illusion on grip formation during prehension. Their experiment showed that this illusion influences the maximum grip aperture (i.e. the maximum distance between the thumb and forefinger) in grasping much less than would be expected on the basis of the illusion’s effect on perceptual judgements. This has caused a wealth of studies debating whether perception and action in healthy subjects use the same visual information (see for instance Smeets and Brenner, 1995, 2001a, c; Brenner and Smeets, 1996; Michaels, 2000; Carey, 2001; Glover and Dixon, 2001a; Plodowski and Jackson, 2001; Smeets et al., 2002).

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Several explanations have been offered for the small but persistent effect of the Ebbinghaus illusion on maximum grip aperture. At one extreme, some authors (Pavani et al., 1999; Franz et al., 2000) have shown that this effect is equal to the perceptual effect if the latter is assessed using another display. At the other extreme, Haffenden and colleagues (Haffenden and Goodale, 2000; Haffenden et al., 2001) have argued that the effect of the display on grasping was not due to the illusion itself, but to the circles in the annuli of the Ebbinghaus illusion acting as obstacles. A possible way to resolve this discrepancy is to look at more aspects of the prehension movement than only the maximum grip aperture (Glover and Dixon, 2001a). Glover and Dixon showed that the effect of the Ebbinghaus illusion on grip aperture decreases gradually during a movement (Glover and Dixon, 2002). They argued that the illusion affected the planning of movements, but not their on-line control. Their argument has been disputed by Danckert et al. (2002), who compared the effect of the illusion at maximum grip aperture with that at three instants before the time of maximum grip aperture. Danckert et al. (2002) reported that the effect of the illusion was smaller at these instants than at the time of maximum grip aperture.

In order to quantify the context-induced illusory changes in size, Glover and Dixon (2002) assumed that the influence of the contextual elements of the illusion was comparable to a change in object size. They therefore quantified the influence of the illusion on grip aperture by finding the change in object size that would have the same influence on grip aperture. However, if the context’s influence on the grip aperture is not completely equivalent to that of a change in size, the resulting ‘Scaled Illusion Effect’ is not a good measure of the illusory change in size. This is so if the contextual elements are considered to be obstacles (Haffenden and Goodale, 2000; Haffenden et al., 2001). In that case, quantifying the influence of the illusion at different times during the prehension movement requires a model that incorporates the influence of obstacles.

Recently, a formal, very simple model has been developed to describe the control of grasping (Smeets and Brenner, 1999, 2001b). In this digit control model, each digit moves as smoothly as possible to an appropriate contact position on the object. The surface at that position is approached more or less orthogonally. For each digit there are two parameters that represent the (visual) information used. One parameter is the above-mentioned contact position, which is the perceived position on the object’s edge that is considered to be appropriate for contacting the object. The other parameter (approach parameter) determines the amount of the trajectory that is more or less perpendicular to the object’s surface. The approach parameter captures all (visual and non-visual) task-variables that influence the required accuracy. The larger the chance that the movement will fail, the larger the approach parameter. Both these parameters influence maximum grip aperture. As perception of the object’s size does not play a role in the digit control model, Smeets and Brenner (1999) argued that illusions of size will not directly affect grip aperture. They suggested instead that a small effect on grip aperture might be caused by a misperception of the contact position. If so, the influence of the