Weber’s law in grasping

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In their reply to our recent paper published in the Journal of Vision (Ganel, Freud, & Meiran, 2014), Heath, Jazi, and Holmes (2015) provide what seems to be a psychophysical interpretation of Weber’s law. Yet their interpretation does not refer to the stimulus and to changes in its size, the true purview of Weber’s law. Heath et al. (2015) focus on the distance between the fingers—a response measure—rather than on the stimulus and the noticed changes along the size of the stimulus, which is subject of Weber’s law. The law is indifferent to the initial size of the comparison stimulus or to the initial opening between the fingers. It refers to the change in the target object needed for detection. As I detail below, the distance between the starting aperture of the fingers and their final aperture is merely a methodological detail rather than a psychophysical aspect of Weber’s law.

Weber’s law describes the relationship between stimulus magnitude and the smallest detectable change in that magnitude. Weber realized that the smallest detectable change in the stimulus is not constant in physical units but rather depends on the magnitude of the stimulus: The larger the stimulus, the larger the just noticeable difference (JND). Moreover, the JND increases linearly with the magnitude of the standard stimulus. In terms of object size, the JND or the smallest detectable change in size, should be larger for larger objects than for smaller objects. In the perceptual domain, different methods have been used to measure the JND. In the method of adjustment, subjects adjust the size of the comparison stimulus to match the size of the target object. The variability of the final estimation response gives the JND for the size of the object in hand (Ganel et al., 2014). In grasping, however, it is problematic to use the final variability in grip as the critical measure because, at this point, the fingers actually touch the target object. We have therefore used values of the maximum grip aperture (MGA) between the fingers as the critical data to measure the JND for object size during grasping (Ganel, Chajut, & Algom, 2008). The point at which the fingers reach MGA has several advantages. First, it is highly correlated with the size of the target object (Jakobson & Goodale, 1991). Second, reaching to later parts of the movement trajectory, it better reflects the sensitivity of the visuomotor system to object size (Jeannerod, 1984). Finally, it is uncontaminated by irrelevant effects of finger velocity (Foster & Franz, 2013; Ganel et al., 2014).

Heath, Jazi et al. argue that the area of uncertainty that defines the JND is modulated by the initial posture of the fingers. The problem with this argument is that the area of uncertainty does not dynamically change as the difference between the starting aperture of the fingers and the size of the object changes (as Heath et al. argue). In point of fact, the area of uncertainty is fixed and is determined only by the size of the target object. Methodological details, such as the size of the initial comparison stimulus or the initial posture of the hand prior to grasp, are simply irrelevant.

Consider the standard perceptual experiment in which the participant is asked to adjust the size of a variable line to match the size of a target line (Ganel, Chajut, & Algom, 2008). The size of the initial line, whether it is small or large, is merely a procedural issue. Weber’s law is the same, and JNDs are the same regardless of whether the starting comparison lines are short or long (Stevens, 1971). Again, Weber’s law in perception is not related to the starting length of the comparison line. It is related to the sensitivity of the perceptual system to the property of the size of the target object. Unlike for perception, the JNDs in grasping do not adhere to Weber’s law (Ganel, Chajut, & Algom, 2008; Ganel, Chajut, Tanzer, & Algom, 2008). Although at initial stages of the grasping trajectory, the opening velocity of the fingers could be faster for large objects, which is reflected by the variance of the response at initial stages of the grasp, this relationship between the fingers’ starting aperture and variance is a methodological aspect of the given experimental condition and could reflect a simple case of speed–accuracy tradeoff (Ganel et al., 2014, experiment 1). When we unconfounded the effects of velocity on an object’s size during grasping, Weber’s law did not hold throughout the entire movement (Ganel et al., 2014, experiment 2). The JNDs for grasping do not adhere to Weber’s law regardless of starting position (Foster & Franz, 2013; Ganel et al., 2014).

Note that in virtually all studies (Ganel, Chajut, & Algom, 2008; Heath, Holmes, Mulla, & Binsted, 2012;
Heath, Mulla, Holmes, & Smuskowitz, 2011; Holmes & Heath, 2013), the differences between the starting aperture and the size of the target object were always well above JND and well beyond the associated area of uncertainty. For example, JNDs in the Ganel, Chajut, & Algom (2008) study were about 3 mm whereas the differences between the starting aperture and the target object size were in the range of 20 to 70 mm (depending on the object size) when the fingers were closed together prior to grasp. In other experiments, when the fingers were kept wide open prior to grasp, the differences between the JNDs and the opening aperture of the fingers were even larger (see Ganel et al., 2014, figure 2a). The difference between the opening finger posture and the size of the target object has therefore nothing to do with the area of uncertainty or with the JND. It simply determines how fast the fingers should open at initial stages of the movement to complete the grasp. 

The discussion of whether or not the speed of the aperture or the impulse force trigger the effects of variability in early stages of the grasp has nothing to do with Weber’s law for object size. Heath, Jazi et al.’s discussion is primarily focused on the difference between the starting position of the fingers and the target object. This difference is not related to the just detectable difference of object size. The initial difference between the starting position of the fingers and the size of the target object is always well above the threshold for size-difference detection. Of course, the differences between the starting position and the sizes of different objects could be attenuated by using faster grip and movement apertures for larger differences (Ganel et al., 2014) or by using larger impulse forces for larger differences (Heath et al., 2012). In either case, this discussion is not relevant to Weber’s law or to JND for object size.

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References


