THE PSYCHOPHYSICS OF VISUALLY DIRECTED WALKING

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Abstract

The present investigation aimed to provide a psychophysical account of visually directed actions. Seven different studies produced during the last eight years by our research group were submitted to Stevens' power law analytical procedures. Those studies were conducted in different experimental environments, under different cue conditions, measuring perceived distance through visually directed walking task and variations of it, e.g., visually directed fractionation. One of these studies also addressed developmental issues. Therefore, many variables that potentially influence exponents of power law were controlled in these studies. Psychophysical analyses showed a general tendency to perceptual constancy, exponents equal to one. The cognitive demands of experimental tasks, the complexity of walking paths, the observers' perceptual tendencies, and some developmental variable, have influences on exponents, usually leading to perceptual underconstancy. The presented results support the validity of visually directed actions, at least for visually directed walking, as a true measure of perceived distance.

Visually directed actions has been used as an indicator of visually perceived distance since the 70's (e.g., Foley & Held, 1972), assuming that this method provides assessment to visually perceived distance. Visually *directed* actions may be usually compared to visually *guided* tasks, the former accomplished without continuous visual monitoring of actual spatial status of observer or observer's limbs, and the latter with this continuous visual monitoring (Foley & Held, 1972). Visually directed actions has been widely used for it provides a measure of visually perceived distance without optic flow field and time-to-contact influences. Even though several investigations provided measures of visually directed action validity (Loomis, Da Silva, Fujita, & Fukusima, 1992; Philbeck & Loomis, 1997; Ribeiro-Filho, Matsushima, & Da Silva, 2003), none has offered an account of the psychophysical relation between the physical properties of space and the perceptual properties of visual space.

The aim of the present study is to provide a psychophysical account of a visually directed behavior, as a preliminary enterprise of a complete psychophysical account of visually directed actions. To achieve our aim, we applied analyzes with Stevens' power law in order to describe the relation between physical distances and the magnitude of perceptual distance as assessed by visually directed walking. This account will be provided by analyzing exponents (n) and constants (k) from power functions of several different experimental data collected during the last eight years. The exponent of power function reflects the observer's perceptual sensitivity to the sensorial continuum. Exponents equal to one indicates perceptual constancy, in other words, that increasing physical dimension by a certain amount will reflect in the same amount of increase in perceived magnitude (Stevens, 1975).

Method

In general, experimental tasks were designed to provide an indicator of visually perceived distance by means of visually directed walking in different environmental settings (from outdoors to indoors settings, from natural scenes to deprived scenes, and so on), and in different task demands (walking toward previously seen target position; avoid collision with an obstacle; and toward the half of a previously seen target distance). One of the studies also dealt with developmental issues, comparing young adults (mean age = 21.8 yrs.) and infant (mean age = 9.1 yrs.) performances.

The general task asked participants to observe carefully the target location, blindfold themselves, and then walk the target distance (or sometimes a fraction of this distance). Some asked to blind walk toward imagined locations, which were imagined relative to a visual obstacle. Still others imposed a 12-sec temporal delay between target observation and walking response. Table 1 summarizes the methods of the several experimental designs and their main differences. Fully descriptions may be found elsewhere (check the References section).

Table 1. Summarized methods for each experimental task

Experimental Task	*Sample (mean age)*	*Range (m)*	*Design*	*Procedures*
Egocentric Walk (Matsushima, unpublished)	8 (20.8)	3–12	Single group	- Toward target
Egocentric Walk (Garcia et al., 2002; Vieira et al., 2002)	12 (20.8)	5–15	Mono x Bino	- Toward target
Egocentric Fractionation (Matsushima et al. 2004)	20 (24.2)	5–15 (2.5–7.5)	Mono x Bino	- Toward half the target distance
Exocentric Fractionation (Garcia et al., 2002; Vieira et al., 2002)	12 (21.6)	5–15	Mono x Bino	- Toward half the target distance
Collision Avoidance (Approaching Pt)				
Adults (Matsushima et al., 1999)	32 (21.5)	2.5–11.5	Perceptual x Imagined x Avoid Points x Time Delay	- Toward target (Perc. and Avoid) - Toward imagined target - Toward target after time delay
Children (8-10 yrs) (unpub.)	7 (9.1)	2.5–11.5	Single group	- Toward target
Collision Avoidance (Departing Pt) (Matsushima et al., 2002)	24 (21.7)	3–12	Perceptual x Imagined x Avoid Points	-Toward target -Toward imagined target
Angular declination (Egocentric) (Ribeiro-Filho et al., 2003)	80 (22.2)	2–5	Mono x Bino Full-cue x Reduce-cue Floor-level x Eye-level	- Toward target
Angular declination (Exocentric) (Ribeiro-Filho, 2000)	20 (20.8)	1–3	Floor-level x Eye-level	- Toward endpoints of interval

Results and Discussion

Walked and physical distances were transformed in their logarithms and then submitted to a linear regression fit, whose parameters are summarized in Table 2. The slope of linear regression represents the exponent of power function and the antilog of the intercept is equal to the constant of power function. Also, *t*-tests performed on exponents compared them to the exponent of perceptual constancy, $n = 1$.

All the exponents reliably differed from zero (all F statistics reached significance) and the linear regressions fit well to data, except for a few cases (in the Angular declination experiment, in the Egocentric task, under Monocular viewing, targets presented at Eye-level, in Reduced-cue environments; and in the Angular declination experiments in exocentric tasks). This indicates that the Stevens' Law, the power function, is a well-suited description to psychophysical relation between physical distance and perceived distance.

Table 2. Exponents of power function and its parameters for each experimental task.

Experimental Task	*Exponent (SD)*	*K*	r^2	*F*
Egocentric Walking				
Matsushima	1.108 (±0.055)*	0.800	0.814	412.342 †
Ribeiro-Filho et al. – Monocular	0.985 (±0.063)*	0.913	0.878	245.177 †
Ribeiro-Filho et al. – Binocular	0.983 (±0.048)*	0.808	0.924	414.120 †
Fractionation				
Egocentric Monocular	0.963 (±0.034)*	0.893	0.901	797.749 †
Egocentric Binocular	0.999 (±0.039)*	0.895	0.879	642.218 †
Exocentric Monocular	0.966 (±0.040)*	1.025	0.944	573.986 †
Exocentric Binocular	1.067 (±0.050)*	0.815	0.931	457.230 †
Collision Avoidance (Approaching Point)				
Perceived Scene	0.978 (±0.013)*	0.933	0.971	6079.210 †
Imagined Scene	0.965 (±0.014)	0.818	0.961	4511.469 †
Avoidance Points	0.943 (±0.017)	0.934	0.945	3183.031 †
Time Delay (Perceived Scene)	0.926 (±0.017)	0.914	0.940	2977.463 †
Children (Perceived Scene)	0.806 (±0.037)	1.073	0.850	463.610 †
Collision Avoidance (Departing Point)				
Perceived Scene	0.972 (±0.015)*	0.972	0.958	4358.429 †
Imagined Scene	0.976 (±0.018)*	0.985	0.942	3073.863 †
Avoidance Points	0.996 (±0.016)*	0.904	0.951	3683.408 †
Angular declination (Egocentric)				
Monocular Eye-level Reduced-cue	0.999 (±0.113)*	0.620	0.398	77.910 †
Monocular Floor-level Reduced-cue	1.033 (±0.061)*	0.698	0.707	284.403 †
Binocular Eye-level Reduced-cue	0.840 (±0.073)*	1.031	0.526	130.774 †
Binocular Floor-level Reduced-cue	1.011 (±0.048)*	0.823	0.790	443.732 †
Monocular Eye-level Full-cue	1.114 (±0.058)*	0.713	0.758	369.629 †
Monocular Floor-level Full-cue	1.226 (±0.040)	0.601	0.888	936.382 †
Binocular Eye-level Full-cue	1.097 (±0.050)*	0.721	0.801	475.137 †
Binocular Floor-level Full-cue	1.215 (±0.050)	0.646	0.833	586.963 †
Angular declination (Exocentric)				
Eye-level Reduced-cue	0.619 (±0.081)	0.631	0.562	66.588 †
Floor-level Reduced-cue	0.587 (±0.091)	0.747	0.445	41.654 †

† $p<0.01$; * one sample t-test (criteria = 1), $p>0.01$

In general, exponents associated to visually directed walking are equal to one, specially when this perceptual response is accomplished in natural environments (Garcia et al., 2002; Matsushima et al., unpublished; Matsushima et al., 1999, 2001, 2004; Vieira et al., 2002). Experimental tasks that rely more on perceptual than cognitive processing also produced exponents of perceptual constancy, e.g., in Collision Avoidance Experiment, for performance associated to approaching point, only Perceptual Scene produced perceptual constancy. Imagined Scene and Time Delay conditions showed underconstancy, probably due to cognitive demands, imagining avoidance points and storage of spatial information for a brief period (12 sec), respectively. In Avoidance Points condition, the features responsible for the underconstancy were the poor visual information provided by the very simple layout (only two small objects, each with 5-cm diameter) associated to a more complex task (2-legs walking task). The influences of these features can be seen in comparisons of similar scene conditions between collision avoidance tasks, walking to approaching point and then to departing point, or walking directly to departing point. The latter, a single-leg walking task, presented perceptual constancy in every scene condition. One may conclude that the more complex are the tasks demands, the more perceptual information was needed to achieve perceptual constancy.

The children also presented underconstancy, a result that integrate to the controversy of perceptual constancy during development, some showing constancy throughout the life span (Verrillo, 1981), and others showing development from underconstancy toward overconstancy (Da Silva, 1983). Another variable associated to this underconstancy in infants may be that infant motor control is not fully developed until adolescence, thus biasing their performance in visually directed walking.

Another psychophysical scalar method also provided evidences for perceptual constancy in visually directed walking performances, the fractionation method, specifically the halving of perceived distance by visually directed walking (Garcia et al., 2002; Matsushima et al., 2004; Vieira et al., 2002). Halving an egocentric distance or an exocentric distance, following binocular or monocular observation of the scene, all of these conditions presented perceptual constancy. They were also a single-leg walking, but they may demand more cognitive processing than a simple egocentric walking. Nevertheless, performance achieved perceptual constancy.

The perceptual constancy of visually directed walking was preserved even when under indoors environments (Ribeiro-Filho et al., 2003), except for the richer cue conditions (Monocular Floor-level Full-Cue and Binocular Floor-level Full-cue conditions) and for exocentric tasks. The former exception may be due to some cue conflict in the full-cue alley, and the latter, to observers' perceptual tendency (such as Equidistant Tendency, see Gogel, 1974), since these experiments were accomplished in a dark alley, toward lightened spheres (6-cm diameter), that were the endpoints of the saggital exocentric intervals; and also to the increase in complexity, since they performed 2-legged walkings.

Another important issue to be addressed is related to memory-based performances and its exponents. A meta-analytical study (Wiest & Bell, 1985) found that exponents for memory-based judgments of distance were smaller than one, compared to perception-based judgments, which exponents were close to one. The general tasks presented in this study can be conceived as a memory-based behavior, since there is no continuous visual monitoring of target spatial status. In addition to the fact that Wiest and Bell found those underconstancy exponents for memory-based judgments, they reported that nonverbal judgments presented exponents even smaller than memory-based judgments. Contrasting those results, and in agreement with the more recent evidence for action-based distance judgments, we found perceptual constancy for almost every condition tested. The present results could contribute to the validity of visually directed actions, at least for visually directed walking, as a true measure of perceived distance.

Concluding Remarks

The present analyses showed an additional evidence for the validity of visually directed actions as a measure of perceived distance. Visually directed walking performances tended to perceptual constancy, despite variations in some important visual cues, e.g., binocular cues. Different psychophysical methods also led to perceptual constancy in responses, as can be seen in fractionation experiments.

Although exponents of visually directed walking tended to one, shifts in exponents, usually toward underconstancy, were observed for some variables. The increased complexity of walking path requires an addition of perceptual information provided by scenes layout, otherwise underconstancy would be found. Tasks with more cognitive demands, such as walking toward imagined target locations or after a 12-sec delay, also led to perceptual underconstancy when associated to more complex walking paths, as showed by perceptual constancy of imagined condition in a single-leg walking path.

Shifts in exponents during development were found here, from underconstancy in infancy to perceptual constancy in adulthood. Although the evidence is controversial, here motor control and not perceptual development may be the responsible for this developmental trend.

In conclusion, one may argue that, with correct balance of tasks demands and cue availability, visually directed walking can be a useful measure of perceived distance, as good as the classical verbal report and other “more perceptual” tasks.

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