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Qualitative features of rectilinear motion: What is perceived as "right"?

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1. Introduction

This study aims to expand on Bozzi's experimental works on Naïve Physics (see Bozzi 1958, 1959, 1990) and Savardi and Bianchi's research into the concept of contrariety as a basic relationship both in the organization of spatial dimensions and in perceptual experience in general (Bianchi & Savardi, 2008a, 2008b; Savardi & Bianchi, 1997, 2000).

Bozzi demonstrated that observers watching pendulum oscillations, objects moving up or down inclined planes or the trajectories of projectiles, immediately perceive a quality, which seems to determine whether the speed of the movement is "natural" or not, i.e. whether it is "the right speed", "slow" or "too slow", "fast" or "too fast". These descriptions did not appear to be arbitrarily connected to the event under observation and were characterized by high inter-subject agreement. Many other classic studies on the expressiveness of motion, in addition to Bozzi's work, have demonstrated that the perception of this quality depends on well-defined spatio-temporal conditions (see for instance Michotte, 1946; Heider & Simmel, 1944; Minguzzi, 1961). The idea that objects possess not only low but also high grade properties (e.g. blue can be light or dark, a gesture may be quick or slow, a rock may give the idea of being comfortable or uncomfortable to sit on) and that these properties are immediately perceived along with other characteristics (such as size, shape or color) is a point of view which is shared by Michotte (1946), Heider & Simmel (1944) and Gibson (1979) and fundamental to studies on both the Experimental Phenomenology of Perception and the Ecological Approach. Indeed this concept has its roots in early Gestalt Psychology (Kopferman, 1930; Köhler, 1938).

Bozzi was the first to notice that the systematic errors which emerged

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during his experiments on pendulum, inclined planes and projectile motion (i.e. which became known as Naïve Physics after McClosky et al. 1980, 1983), might depend on the way in which we naturally perceive movements and velocities. In particular, he studied the perceived "rightness" or "naturalness" of motion (Bozzi, 1958, 1959, 1991).

More recent studies on Naïve Physics do not make reference to this perceived "rightness" of motion (see for instance Frick et al., 2005; Hubbard, 2006; Huber & Krist, 2004; Oberle et al., 2005; Rohrer, 2003 and even those researchers who explicitly developed Bozzi's early studies on pendulum motion and motion along inclined planes such as Pittenger, 1985 and Pittenger & Runeson, 1990). Some focused on accuracy in the perception of velocity, observing people playing tennis and baseball with particular regard to the relationship between the speed of the ball and how accurately people made contact with it (Huber et al., 2004; Oberle et al., 2005). Some focused on false beliefs regarding the physical laws pertaining to motion in pendulum, moving objects, projectiles and to movements reflected in mirrors (Mc Closkey et al., 1980, 1983; Bertamini et al., 2003). Others focused on the roles played by action and perception and the differences between them (see for instance Rohrer, 2002; Frick et al., 2005; Huber et al., 2003; Krist et al., 1993).

Analyzing what is perceived to be the "right" speed is, we believe, an important aspect of the study of the Experimental Phenomenology of Perception and might contribute significantly to the debate on Naïve Physics, which has been developing over the last 30 years.

2. The Experiment

A *range* of speeds perceived as being "right" in a simple condition of uniform rectilinear motion was investigated. The aim was also to determine which area of the fast-slow dimension this range covers.

An object that falls freely, for instance an apple, has a specific way of falling – it falls "heavily" due to gravity. Similarly, in a computer animation, a little square sliding down an inclined plane has specifically "right" ways of sliding: it seems to slide "as if on ice" reaching a certain velocity, or to slide on a "soaped path" at a different velocity and observers are able to select the "right" speed – for each of these kinds of motions – among a series of speeds (Bozzi, 1990). In the experiment described here, we explored simple movements: black discs moving along uniform rectilinear paths. We aimed to identify a range of speeds which are perceived by observers as being "right" with respect to other two ranges of speeds, respectively "slow" and "fast". In particular we wanted to understand:

1) whether, even for very simple movements, there is a clear range of speeds which participants consistently describe as "right", and whether this is significantly different from the ranges of speeds described as "fast" or "slow";
2) what relationship there is between the ranges of speeds perceived as "right", "fast" and "slow";
3) whether the direction of the movement influences the speed perceived as being "right". As Bozzi noted, if a pendulum swings from the bottom up - like a windscreen wiper – as opposed to swinging from the top down as is usually the case, then the speed perceived as "right" is different (Bozzi, 1990).

2.1. Subjects

Fourteen expert and non-expert adult participants from the University of Verona took part in the experiment. They all had normal or correct-to-normal vision.

2.2. Apparatus and Stimuli

Participants observed the image of a black disc with a diameter of 1.5 cm moving with a uniform rectilinear motion on a computer Sony Triniton Multiscan 420 monitor (monitor frame rate: 60Hz; 1600 x 1200 pixel resolution). A circular reduction screen (with a diameter of 20 cm) was placed in front of the screen in order to avoid the potential stereoscopic effect induced by the looping motion of the disc.

A series of eight different moving images was presented to each participant. The images moved in one of 8 directions (see Figure 1); the dimension and color of the disc, the size of the reduction screen and the distance of the observer from the computer screen were kept constant.

The 8 directions and the starting speed were randomized within and between subjects and varied from 1 to 20 pixels per frame. Observers could adjust the speed of the disc frame by frame using two keys (the left arrow to reduce the speed, the right arrow to accelerate).

Participants were asked to adjust the speed of the disc to a target speed established at the beginning of each trial and indicated on the computer screen as "fast", "right" or "slow". It was made clear that they had to decide at what points in range the speed corresponded to "right", "fast" or "slow".

They were invited to explore the entire range of speeds (by pressing the space bar) before choosing their response. The experiment started with a demo in order to familiarize participants with the task.

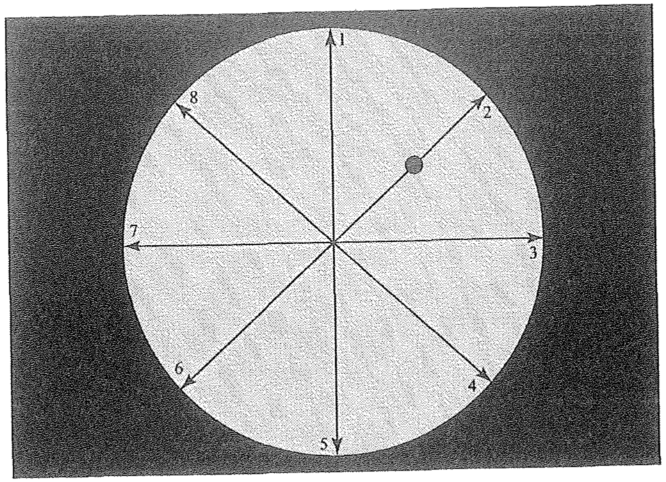

Figure 1. The eight directions of motion studied in the experiment.

2.3. *Results*

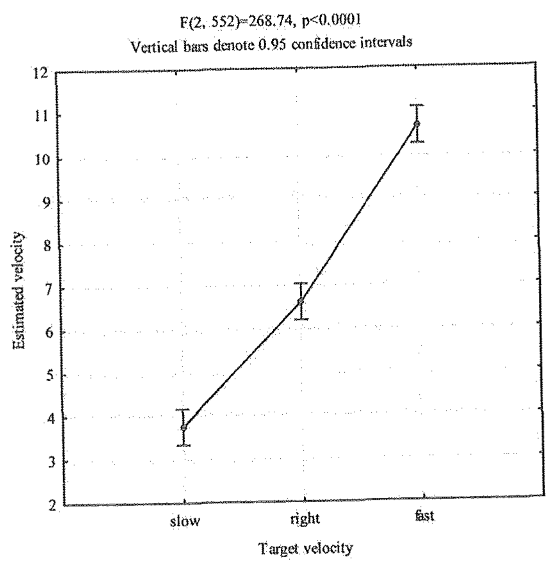

Figure 2. Estimated velocity of the three target velocities (slow, right, and fast).

Figure 2 shows the distribution of the three groups of responses: 1) slow; 2) right; 3) fast. A one-way ANOVA was performed on the target velocities: the difference between the three types of responses was highly significant (p-value < 0.0001. See Figure 2).

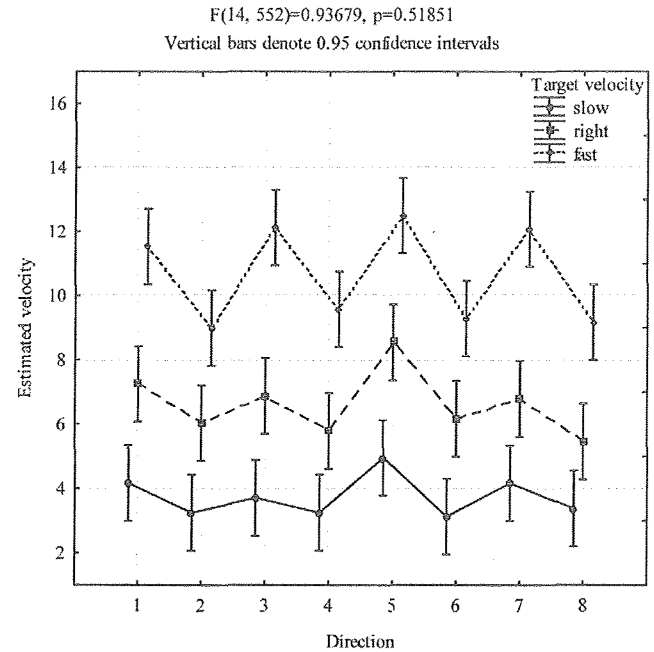

Figure 3. Estimated velocity of "right", "slow" and "fast" in the 8 directions of movement (for the directions, see Figure 1).

We also found that the direction of the movement had a strong influence ($p=0.015$) when the target velocity was "right" ($p < 0.002$) and "fast" ($p < 0.0001$). The post hoc analysis (Bonferroni test) showed that when the target velocity was "right", there were significant differences between directions number 2 and 5 ($p<0.05$), 4 and 5 ($p<0.01$), and 5 and 8 ($p<0.01$). When the target velocity was "fast", there were significant differences between directions number 2 and 5 ($p<0.02$), 5 and 6 ($p<0.05$), and also 5 and 8 ($p<0.05$). Thus, in both cases, the differences mainly concerned downward vertical movements when compared to upward diagonal movements.

The spontaneous reports of the participants at the end of the experiment went a long way towards explaining these differences. They said that in image number 5, the object appeared to be falling due to the force of gravity. In contrast, the disc in image number 8, where it moved diagonally upwards, was described as rising against the force of gravity like "a flipper ball". The speeds perceived as "right" in the images where the disc went diagonally downwards (numbers 4 and 6) corresponded to a type of fluid downward gliding motion, "with no friction", like the movement of a skier or a ball rolling down a slope. Finally, in the images showing horizontal movements (numbers 3 and 7), participants reported that the disc seemed to be like a rolling billiard ball or an object, which moves effortlessly without friction.

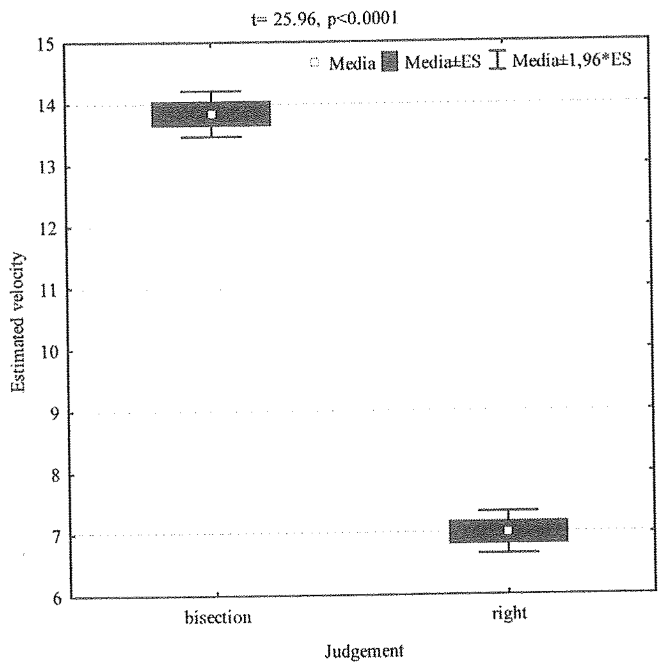

Figure 4. Estimated velocity in the two tasks.

3. A comparison with a bisection task

The results of experiment 1 confirmed the existence of a perceived "right" velocity within a specific range of speeds, demonstrated the effect of spatial directions and established the existence of specific spatio-

temporal structures corresponding to the "right" motion. These structures can be clearly identified and are distinct from those that correspond to "slow" and "fast" movements. However, there remains the doubt that what participants were doing when describing the "right" speed was bisecting the slowest - fastest speeds presented. For this reason, a control experiment was carried out.

This second experiment differed from the first experiment only in that the speed of the stimuli varied along a fixed gamma (20 pixel per frame). In particular, the "slowest" velocity varied from 1 to 6 pixel per frame (which corresponded to a perceptually "slow" speed) and the "fastest" velocity from 21 to 26 pixel per frames (which corresponded to a perceptually "fast" speed).

Two groups of participants were asked to:

1) select the "right" speed;

2) bisect the range of speeds presented.

In each session, a series of 96 moving images was presented (the 48 moving images in experiment 1 multiplied by two ranges of speeds).

The analysis of the data (independent sample T-test) revealed a significant difference between the results obtained in the task where participants were asked to find the "right" velocity and the results of the bisection task (see Figure 4).

4. Conclusions

Bozzi interpreted Naïve Physics as simply a chapter in Experimental Phenomenology, which focuses on the perceived features of motion (Bozzi, 1961, 1990). This study aimed to shift the search for the "right" quality of motion beyond its preliminary context of applications (pendulum motion, motion along inclined planes and projectiles). The results confirm that the speeds perceived as "slow", "right" and "fast" correspond to precise structures of motion and that the "right" speed has a precise phenomenal identity, independent from a simple bisection of the ranges of perceived speeds.

Further studies would clarify the relationship between the range of speeds perceived as "right" and the range of speeds perceived as "intermediate". Preliminary results revealed that the two do not coincide.

In brief, we believe that the present study, despite being only an initial step, in any case represents a promising departure point for a deeper analysis of the expressive features of inanimate motion in terms of the fast-slow dimension.

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Abstract

The experiments extend the investigation on the existence of a range of speeds perceived as "right" to include uniform rectilinear motion. Bozzi (1958, 1959,1990) previously worked on this area studying pendulum oscillation, trajectories of projectiles and objects moving down inclined planes (1958, 1959, 1990). Our results confirmed the existence of different ranges of speeds perceived respectively as "slow", "right" and "fast" and proved that the "right" speed does not coincide with what one would expect using a simple bisection of the extremes "fast" and "slow".

Riassunto

I due esperimenti presentati estendono al caso del moto rettilineo uniforme la verifica dell'esistenza di un movimento percepito come "giusto" - già dimostrata da Bozzi (1958, 1959,1990) rispetto al movimento di pendoli, proiettili e corpi in discesa lungo piani inclinati. I risultati hanno confermato l'esistenza di diversi *range* di velocità corrispondenti all'esperienza del "veloce", "lento" e "giusto", dimostrando che la velocità percepita come "giusta" non coincide con quanto ci si sarebbe dovuti attendere sulla base di una semplice bisezione degli estremi veloce-lento.

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