Bistable Alternation of Point-Light Biological Motion

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Abstract. The facing-in-depth of point-light biological motion is ambiguous: the frontal and back view look the same. However, since earlier studies found a very strong perceptual bias in point-light biological motion, it is unknown whether it evokes an alternating (bistable) percept. In the present study, naive, untrained observers viewed point-light stimuli in half-profile view. All participants experienced spontaneous flipping of the orientation-in-depth, both for biological motion and necker cube displays. The number of perceptual flips was lower for the rocking cube than for the static one; and higher for biological motion than for rocking cubes. Contrary to earlier findings the participants did not have a perceptual bias. We conclude that ambiguous biological motion does evoke a bistable percept.

1 Introduction

Ambiguous visual stimuli are highly interesting for studying brain dynamics, because the brain is forced to arrive at a consistent interpretation, on the basis of the dynamical interaction of neuronal populations. Ambiguity may, e.g. lead to a simultaneous, conflicting percept (e.g. motion transparency), or to spontaneous spatial and temporal alternation of the conflicting percepts (e.g. necker cube or binocular rivalry). Biological motion displays human movements as moving point lights [1]. For a non-profile view, the facing-in-depth is ambiguous, i.e. there is no way to tell whether one sees the front or the backside. Biological motion is a particularly interesting ambiguous stimulus, because it is a complex stimulus with very little information, and requires high-level visual processing [9].

Ambiguous displays of 3-D objects often evoke a bistable percept. The well-known necker-cube displays the ribbons of a cube without perspective deformation nor occlusion. If one looks at a necker cube for some time, the percept will be bistable or even multistable. That means that the percept will spontaneously change to a different possible percept, such as two possible 3-D interpretations, or even a flat wireframe [3]. Alternating percepts are thought to arise from the dynamical competition between neuronal cell populations that each represent possible, but mutually exclusive, percepts [4].

One could expect that the percept of point-light biological motion is bistable, like the necker cube. However, biological motion differs from the necker cube because it moves, and it differs from dynamic displays such as the rotating drum

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[5] in that its form changes dynamically. Thus, rhythmic biological motion might be special in that the perceptual dynamics interfere with the cyclic change in form. Moreover, observers have strong perceptual bias to see the frontal view [2, 6]. We investigate whether biological motion displays are bistable[1]. Since perceptual changes are linked to the amount of conflict in the stimulus [4], a strong perceptual bias could abolish the bistable percept of biological motion.

2 Methods

Stimuli were computed, using in-house developed programs, and were presented on a CRT monitor, 40x30 cm, 640x480 pixels, 180 Hz vertical refresh. Participants wore CrystalEyes-3 stereo goggles so the effective refresh rate was 90 Hz per eye. All stimuli consisted of 14' red dots on a dark background.

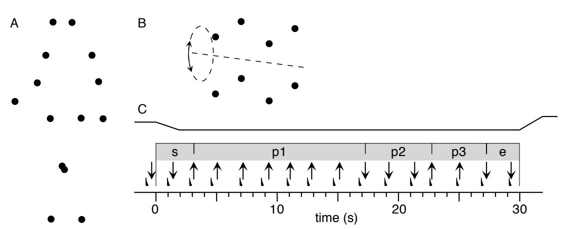

Fig. 1. The walking stimulus (A) and the necker cube (B). C. A 30-s interval of presentation. Upper trace: the presented condition with a transitional period on the first two s. Triangles depict the auditory cue to respond (arrows). In this example, there are three perceptual intervals: p1, p2, p3.

Stimuli represented a repeated walking cycle without net displacement [7], or a cube (Fig. 1). The walker consisted of 14 dots, and was oriented 45 about the vertical. The cube consisted of 8 dots located on the corners. The cube was oriented 45 about the vertical and tilted 25. When rocking, a sinusoidal tilt was applied with an amplitude of 10. All stimuli were 3 wide. The movement period was always 1.4 s.

The experiment consisted of three 5-min. sessions, respectively presenting biological motion, rocking cubes, and stationary cubes, repeated on two days. During each experimental session, the stimulus was continuously displayed. Every 30 seconds, an invisible, smooth transition to a different condition occurred (each condition occurred twice in each session). The condition of interest displayed an orthographic projection. Four other conditions that were not analyzed here, applied different depth cues to the stimulus. Each condition occurred twice during a session.

The nine participants did not know our goal, and were inexperienced with psychophysical experiments. The task was to report the current percept by a key-press on hearing a brief bell sound, on average every other second with a random jitter of 0.5 s (Fig. 1C; [8]). Valid responses were "Toward", "Flat", or "Away" for a walker or "From Above", "Flat", or "From Below" for a cube.

[1] Notice that we use bistability in the usual sense [3, 4], which is different from [2].

The perceptual intervals were selected from each 30-s presentation period. Only intervals were selected that started and ended with a perceptual change within this period. If no such interval was present, a 29-s interval was assumed. The cumulative distributions of response intervals were statistically compared using a bootstrap-version of the Kolmogorov-Smirnov test (ks.boot, R version 2.8), with 10^5 bootstraps.

3 Results

Figure 2 shows the cumulative perceptual intervals over all participants. The saturation of the distributions above 10 s shows that most intervals lasted less than 10 s. The jump at the last bin reflects that a number of 30-s periods consisted of just a single long perceptual interval that was interrupted at the end of the trial. This occurred most frequently in the rocking cube condition. All participants experienced at least one interval of 15 s or shorter in each condition. Thus, spontaneous perceptual changes occurred in all three conditions.

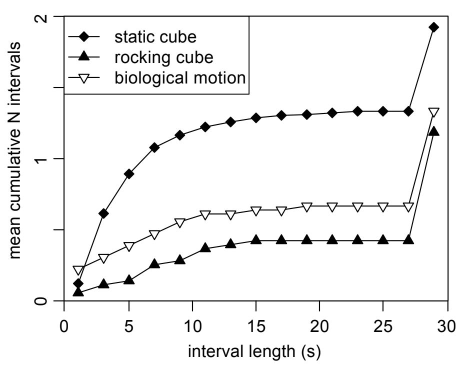

Fig. 2. Mean cumulative distributions of perceptual intervals. The last bin includes intervals that were interrupted by the end of the presentation period.

The cumulative distribution for biological motion lies in between those for the static and rocking Necker-cubes (Fig. 2). There were more short intervals for static cubes than for biomotion (ks.boot-P < 0.0001), and more short intervals for the latter than for rocking cubes (ks.boot-P $= 0.0001$). This shows that periodic motion reduces the number of short perceptual intervals, and thus the number of spontaneous perceptual changes. Importantly however, the result shows that the percept of point-light biological motion is bistable. The number of perceptual changes was considerably lower than for static necker cubes, but more than in a rocking Necker-cube, which had a comparable amount of movement as the walking stimulus.

A “Flat” response was given just once for biological motion, but were frequent with static and moving cubes (10% of the intervals of <15 s). Remarkably, none of the participants showed a strong perceptual bias either for biological motion or for the static or rocking cube. Of the <15 s intervals 55% were “towards” and 43% were “away” responses for biological motion (43% to 49% for the necker cube). The same was found for the total viewing time: 53% of all responses were “towards” to 47% “away” for biological motion (49% to 45% for the necker cube).

4 Discussion

The present results show that point-light biological motion is a bistable stimulus, in the sense that the two possible percepts (frontal versus back view) alternate spontaneously when one looks at it for some time.

A remarkable finding of the present study is that the perceptual bias for a toward-percept was hardly present in our data, in contrast to published results [2, 6]. This apparent discrepancy probably is not due differences between the displays. We asked a number of naive observers, and verbally they reported almost invariably a "toward" view of the walker. A possible explanation is that the perceptual bias is weak, and therefore easily suppressed; for example by depth cues such as linear perspective deformation, or occlusion. In the present study the participants did not have a forced choice but reported the depth percept over a longer period, which probably strongly reduced the bias.

Since ambiguous stimuli have multiple interpretations, the brain needs to arrive at a consistent interpretation. The cyclic motion that imposes the brain with a gradual form change might interfere with this dynamic process. Indeed, the spontaneous perceptual changes in necker cubes were almost abolished by rocking motion in our population of inexperienced observers.

In biological motion the gradual, cyclic form change did not abolish spontaneous perceptual changes, but compared to the static necker cube, did reduce them. Since there was no perceptual bias, we find it unlikely that the biological motion stimulus suffered from reduced perceptual conflict [4]. Also, the form change did not abolish the bistability as in the necker cube. Instead, we propose that there is a neuronal conflict at a neuronal level that integrates the complete walking cycle, which is consistent with cell recordings in monkeys [9].

References

1. Johansson, G.: Visual perception of biological motion and a model for its analysis. Percept. Psychophys. **14** (1973) 201–211
2. Vanrie, J., Dekeyser, M., Verfaillie, K.: Bistability and biasing effects in the perception of ambiguous point-light walkers. Perception **33** (2004) 547–560
3. Kornmeier, J., Bach, M.: The necker cube–an ambiguous figure disambiguated in early visual processing. Vision Res. **45** (2005) 955–960
4. Brouwer, G.J., Tong, F., Hagoort, P., van Ee, R.: Perceptual incongruence influences bistability and cortical activation. PLoS ONE **4** (2009) e5056
5. Pastukhov, A., Braun, J.: A short-term memory of multi-stable perception. J. Vis. **8** (2008) 1–14
6. Vanrie, J., Verfaillie, K.: Perceiving depth in point-light actions. Percept. Psychophys. **68** (2006) 601–612
7. Lange, J., Lappe, M.: A model of biological motion perception from configural form cues. J. Neurosci. **26** (2006) 2894–2906
8. Mamassian, P., Goutcher, R.: Temporal dynamics in bistable perception. J. Vis. **5** (2005) 361–375
9. Oram, M.W., Perrett, D.I.: Responses of anterior superior temporal polysensory area (STPa) neurons to "biological motion" stimuli. J. Cogn. Neurosci. **6** (1994) 99–116