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ORAL PAPER

Vision-for-perception and vision-for-action in typical development, autism, and Parkinson's disease

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Introduction

According to the two-visual-system hypothesis (Milner and Goodale 1995), after V1 the visual system splits into vision-for-action and vision-for-perception modules. Specifically, the dorsal subsystem is proposed to specialize in the visual guidance of actions, whereas the ventral subsystem in object perception and recognition. Support for the two-visual-systems hypothesis has come from monkey and human studies using a variety of techniques, including neuroimaging, neuropsychological, neurophysical, psychophysical, and behavioral methods (for a recent review, see Goodale and Westwood 2004). In particular, four commonly accepted criteria for the modularity of cognitive systems are broadly tested in the literature: association with fixed neural architecture, obligatory output, information encapsulation, and specific breakdown patterns after damage (Fodor 1983).

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Very few studies have tested other criteria for modularity, such as, for instance, the idea that independent modules may exhibit characteristic pace and sequencing in their ontogenetic development. Rival et al. (2004), among others, studied motor and perceptual responses to illusions in children. They reported that visuomanual pointing responses were unaffected by illusions, whereas visual matches were. However, current opinions diverge on the interpretation of dissociations between perceptual and motor tasks in visual illusions (Bruno 2001; Carey 2001; Franz 2001; Milner and Dyde 2003) and therefore these findings are not conclusive.

Method

We investigated the performance of different groups of participants in two spatial tasks. Both tasks required the visual appreciation of a spatial extent, but they involved different responses. In the blindwalking task, participants were required to walk, while blindfolded, to a near target that was shown immediately before starting to walk. In the other task, which we call "L-pattern matching" task, they were required to adjust the length of a frontal rope to match the apparent length of a second rope extending in front of them along the sagittal plane. In this way, in the blindwalking task participants adopt an egocentric frame of reference, performing the task after coding the location of the target relative to their body. Adults (Thomson 1983) and children (Mauerberg-deCastro and Moraes 2002) can perform such actions with remarkable accuracy if they start immediately after putting the blindfold. Conversely, in L-pattern matching task, participants visually compared the lengths of two ropes (an allocentric frame of reference) and did not move (Loomis et al. 1992).

Studies of "walkable" illusion patterns suggest that a common visuomotor system subserves both upper and lower-limb movements (Glover and Dixon 2004; Wraga et al. 2000). Given these studies, the other features of our tasks, and the current characterization of the hypothesized dorsal and ventral modules (Haffenden and Goodale 1998; Goodale and Milner 2004), we reasoned that blindwalking should recruit resources from the dorsal system, whereas matching should recruit resources from the ventral system.

Testing was performed in controlled rooms, with no furniture, high ceilings and a relatively irregular texture on the floor.

Each participant was tested individually and contributed only one trial in each task.

The order of tasks was randomized across participants. In the blindwalking task, participants were blindfolded and positioned at a fixed starting location within the room. A target was placed in front of them at a randomly chosen distance between 3 and 6 m. The blindfold was removed for three seconds and then applied again. Participants immediately walked to the previously viewed target until they felt to be where the target had been. To prevent participants from obtaining acoustic or haptic cues when stepping on the disk, a collaborator silently removed the cardboard disk from its location as soon as the walk began. At this point, one of the experimenters measured and recorded the walked distance. No participants reported having practiced blindwalking before.

In the L-pattern matching task, participants sat on a chair and were instructed to look at the target disk, also previously placed at a randomly chosen distance between 3 and 6 m, with a rope laid down on the ground from the chair to the target. Participants adjusted the length of a second rope, presented frontally to form an L-pattern on the ground, until it matched the apparent length of the first rope. Adjustments were performed by giving verbal instructions to a collaborator and were not constrained temporally.

We tested, first of all, typically developing school children performance versus adult performance with the aim of testing the two-visual-system hypothesis with respect to the ontogenetic criterion and to collected data on the development of vision-for-perception and vision-for-action along the life span. Evidence for these differences would be consistent with characteristic patterns of ontogenetic development, which one may expect if the dorsal and ventral system act as functionally separate processing module. In the second and third experiment, we assessed two groups that are likely to show alterations of visual processing (for a review, see Mitchell and Ropar 2004; Bondi and Tröster 1997), i.e., autistic children and adults with Parkinson disease (PD). We aimed to determine whether these two pathologies influence vision-for-perception and vision-for-action in similar or different ways.

In all studies, to protect the rights of all participants the guidelines of the Italian board of psychologists were strictly followed.

Experiment 1: Participants

The first group of participants was composed of 26 typically developing children [11 males and 15 females; mean age (SD) = 7 years and 1 month (4 months)] attending the first class of Italian primary schools. The second group was composed of 33 children (20 males and 13 females) attending the third class. The third group, finally, was composed of 41 adults (19 males and 22 females; mean age (SD) = 26 years and 2 months (9 years); mean schooling (SD) = 14 years and 1 month (2 years)]. To screen for verbal and non-verbal cognitive abilities, we also tested all children with the Peabody Picture Vocabulary Test-revised (Dunn and Dunn 1981; Stella et al. 2000) and with Raven's Coloured Progressive Matrices (Raven 1956, 1991; Pruneti et al. 1996). Adults completed a questionnaire to identify the possibility of neurological impairments.

Experiment 1: Results

In the blindwalking task all the participants showed a very precise and accurate performance, in spite of the tendency of younger children to be less precise and commit larger errors. However, no statistically significant differences emerged comparing 1st grade, 3rd grade, and adults groups.

On the other hand, in the L-pattern matching task an interesting developmental pattern emerged in the three groups performance. All participants, as expected, underestimated distances. In particular, 3rd grade children showed a larger underestimation than adults, and 1st grade children showed a larger underestimation than both the other groups.

Experiment 2: Participants

Autism is a pervasive developmental disorder characterized also by anomalies in visual abilities (Mitchell and Ropar 2004), but it is not clear which level of visual processing is damaged. Also with the aim of trying to light particular perception abilities and disabilities in autism, we assessed a group of 15 male children [mean age (SD) = 10 years (3.3 years)] with diagnosis of high functioning autism, who showed good verbal comprehension abilities and did not present clumsiness. Three control groups were also tested in the same tasks: (1) typical development children matched on mental age, assessed with the RCPM ($N = 18$; mean age (SD) = 7 years (0.3 months)]; (2) typical development children matched on chronological age [$N = 15$; mean age (SD) = 10 years (8 months)]; (3) adults who could attend the institute of autistic children and were consequently tested in the same room as autistic children in order to control room influences [$N = 12$; mean age (SD) = 29 years (4 years)].

Experiment 2: Results

In the blindwalking task all groups performance was similar, in spite of a small tendency in high functioning autism group to underestimate distance, which seemed to depend on age. Nevertheless, autistic children performance in the L-pattern matching task was clearly different from all other control groups: they seemed not to feel a perceptive effect due to horizontal versus vertical lines; indeed, autistic children showed an unexpected accuracy and precision in matching distances.

These results suggest that autism is associated with selective abnormalities of the ventral visual system.

Experiment 3: Participants

Parkinson disease is a degenerative central nervous system pathology, impairing in particular motor abilities, but in many cases it affects also cognitive functioning and in particular visual space perception (Mosimann et al. 2004) even though it is not clear which level of visual abilities is damaged by the pathology. Two groups of participants took part in the third experiment. The first group was composed of 14 PD patients [eight males and six females; mean age (SD) = 67.7 years (SD = 6.11 years); mean schooling (SD) = 8.43 years (4.16 years)], who were selected on the basis of two criteria: diagnosis no more than 10 years ago, no dementia. All participants were assessed during the on-phase with respect to their drug program.

The second group was composed of ten control participants matched on mean age and schooling to the experimental group [four males and six females; mean age (SD) = 64.2 years (SD = 8.22 years); mean schooling (SD) = 8.10 years (3.66 years)].

Experiment 3: Results

In the blindwalking task PD patients systematically walked less than real distance. On the other hand, they performed as good as the control group in the L-pattern matching task.

Again the studied pathology, i.e., PD, influenced vision-for-action and vision-for-perception systems in different way.

Conclusions

These studies are consistent with independent vision-for-action and vision-for-perception subsystems that develop at different paces and speeds and are affected in different ways by different pathologies. At least for locomotion, vision-for-action appears to develop more quickly and to be essentially mature at 6–7 years of age. As a consequence, children's representation of distance when they program a short walk is comparable to that of adults, and both are accurate. Vision-for-perception, conversely, appears to develop more slowly. Moreover, PD participants systematically underestimate distance in blindwalking, but show performances comparable to control in the L-pattern matching task. This pattern of results may evidence a specific difficulty in processing visual information to guide action, while visual perception is not affected. On the other hand, the surprising performance of autistic children in the L-pattern matching suggest that autism may involve anomalies in the use of spatial reference frames in visual cognition.

References

Bondi MW, Tröster AI (1997) Parkinson's disease: neurobehavioural consequences of basal ganglia dysfunction. In: Nussbaum PD (ed) Handbook of neuropsychology and aging. Plenum, New York, pp 216–245

Bruno N (2001) When does action resist visual illusions? Trends Cogn Sci 5:379–382

Carey DP (2001) Do action systems resist visual illusions? Trends Cogn Sci 5:109–113

Dunn LM, Dunn LM (1981). Peabody picture vocabulary test. American Guidance Service, Minnesota

Fodor JA (1983) The modularity of mind. An essay on Faculty Psychology. The MIT Press, Cambridge

Franz VH (2001) Action does not resist visual illusions. Trends Cogn Sci 5:457–459

Glover S, Dixon P (2004) Likelihood ratios: a simple and flexible statistic for empirical psychologists. Psychon Bull Rev 11:791–806

Goodale MA, Milner AD (2004) Sight unseen. An exploration of conscious and unconscious vision. Oxford University Press, Oxford

Goodale MA, Westwood DA (2004) An evolving view of duplex vision: separate but interacting cortical pathways for perception and action. Curr Opin Neurobiol 14:211–230
Haffenden AM, Goodale MA (1998) Independent effects of pictorial displays on perception and action. Vis Res 40:1597–1607
Loomis JM, Da Silva J, Fujita N, Fukusima SS (1992) Visual space perception and visually directed action. J Exp Psychol Hum Percept Perform 18:906–921
Mauerberg-deCastro E, Moraes R (2002) Distance perception in children while walking. Psicol Reflexao Crit 15:373–381
Milner AD, Dyde R (2003) Why do some perceptual illusions affect visually guided action, when others don't? Trends Cogn Sci 7:10–11
Milner AD, Goodale MA (1995) The visual brain in action. Oxford University Press, Oxford
Mitchell P, Ropar D (2004) Visuo-spatial abilities in autism: a review. Infant Child Dev 13:185–198
Mosimann UP, Mather G, Wesnes KA, O'Brien JT, Burn DJ, McKeith IG (2004) Visual perception in Parkinson disease dementia and dementia with Lewy bodies. Neurology 63:2091–2096
Pruneti C, Fenu A, Freschi G, Rota S, Cocci D, Marchionni M, Rossi S, Baracchini Muratorio G (1996) Aggiornamento della standardizzazione italiana del test delle Matrici Progressive Colorate di Raven (CPM). Boll Psicol Appl 217:51–57
Raven JC (1956) Guide to using the coloured progressive matrices, sets A, Ab, and B. H.K. Lewis. London
Raven JC (1991) CPM—coloured progressive matrices. O.S. Organizzazioni Speciali, Firenze
Rival C, Olivier I, Ceyte H, Bard C (2004) Age-related differences in the visual processes implied in perception and action: distance and location parameters. J Exp Child Psychol 87:107–124
Stella G, Pizzoli C, Tressoldi PE (2000) Peabody-Test di vocabolario recettivo, PPVT-revised. Omega, Torino
Thomson JA (1983) Is continuous visual monitoring necessary in visually guided locomotion? J Exp Psychol Hum Percept Perform 9:427–443
Wraga M, Creem SH, Proffitt DR (2000) Updating displace after imagined object and viewer rotation. J Exp Psychol Learn Mem Cognit 26:151–168