Polish Psychological Bulletin
2012, vol. 43(3), 151-166
DOI - 10.2478/v10059-012-0017-2

Original Papers

*Styrkowiec Piotr**
*Nęcka Edward***

Perceptual global processing and hierarchically organized affordances – the lack of interaction between vision-for-perception and vision-for-action.

Abstract: In visual information processing, two kinds of vision are distinguished: vision-for-perception related to the conscious identification of objects, and vision-for-action that deals with visual control of movements. Neuroscience suggests that these two functions are performed by two separate brain neural systems – the ventral and dorsal pathways (Milner and Goodale, 1995). Two experiments using behavioural measures were conducted with the objective of exploring any potential interaction between these two functions of vision. The aim was to combine in one task methods allowing for the simultaneous capture of both perceptual global processing and affordance extraction and to check whether they influence each other. This aim was achieved by employing the paradigms of Navon (1977) and Tucker and Ellis (1998). A compound figure was created made up of objects with handles that might or might not have orientation congruent between levels. The results revealed that while the affordance effect occurred every time, the Navon effect appeared only when subjects focused their attention on object elements responsible for inconsistence within compound figure. Most importantly, even when these two effects occurred at once, they had no effect on each other. Results from the study failed to confirm the hypothesis about interaction and gives support to the view that vision-for-perception and vision-for-action tend to act as separate systems.

Keywords: *perceptual global processing, affordances, visuo-motor information processing*

The current approach to information processing in the human brain assumes that these processes operate rather together then separately and in a parallel rather than in a serial mode. Vision is no exception and at present, it is widely agreed that there are two visual functions working together: vision for perception and vision for action. One of several theories that are based on this idea is the hypothesis of Milner and Goodale (1992, 1995) which assumes that vision for perception and vision for action are mediated by two distinct neuronal systems in the human brain – the ventral and dorsal streams. Although the claim that these two neural streams might represent two approaches to visual cognition (a constructivism approach and a separate ecological approach) seems to be rather far-fetched (see Norman, 2002, and related comments), the assignment of these two distinct functions of vision to the two brain systems is valid. According to Milner and Goodale (1995), the ventral stream, which runs from the primary visual cortex in the occipital lobe to regions in the temporal lobe, deals with conscious object recognition and the representation of forms. On the other hand, the dorsal stream, which runs from the primary visual cortex to the parietal lobe, is supposed to act as a visual coordinator for motor activity that operates mostly beyond conscious control.

There is a large body of evidence supporting the theory of Milner and Goodale, in most cases demonstrating the separation between vision for perception and vision for action. Evidence comes from neuropsychology (cases of double dissociation and patients with visual agnosia or optical ataxia, see Milner and Goodale, 1995), neuroimaging studies (Haxby et al., 1994; Culham and Kanwisher, 2001; Grill-Spector, 2003; Goodale and Westwood, 2004; Shmuelof and Zahary 2005; Valyear et al., 2006) and behavioural studies – the latter based mainly on the employment of visual illusions (Aglioti et al., 1995; Brenner and Smeets, 1996; Bridgeman et al., 1997; Haart et al., 1999). In the case of studies using visual illusions, some doubts have been expressed (see Vishton et al., 1999; Franz et al., 2001). However, it seems

*** Institute of Psychology University of Wrocław, Poland**
**** Institute of Psychology Jagiellonian University, Kraków, Poland**

that such measures - when used with reservations being taken into account - may be considered as firm evidence for the dissociation between the functioning of the ventral and dorsal streams as postulated by Milner and Goodale's theory (e.g., Króliczak et al., 2006).

The model proposed by Milner and Goodale cannot of course avoid criticism, which relates mainly to the issues that this model is oversimplified and does not sufficiently explain the way potential interactions between vision for perception and vision for action occur (Bruce et al., 2003). That there are such interactions, and that these two aspects of vision affect each other, we know from studies carried out beyond the model of Milner and Goodale (e.g. Craighero et al., 1998, Craighero et al., 1999). Neuroanatomical studies show that the distinct brain systems discussed are highly interconnected (see Dougherty et al., 2005; Pisella et al., 2006; Mather, 2009). Moreover, many studies, using different techniques conducted within the model, demonstrate interaction between the functioning of the ventral and dorsal streams (e.g., Koshino et al., 2005; Adamo and Ferber, 2009). In a recent paper in which Milner and Goodale reviewed the current state of their theory (Milner and Goodale, 2008), the researchers considered some of the potential interactions between the ventral and dorsal streams, but to a very limited extent. As we still do not know a great deal about these issues on the grounds of Milner and Goodale's theory, the present study intends to explore potential interplays between vision for perception and vision for action. To this end, two behavioural effects, each representing the functioning of the ventral and dorsal streams respectively, are imposed on each other in one task.

In order to activate vision for perception, the perceptual effect of global processing is used. This effect was discovered by Navon (Navon, 1977). He demonstrated this effect using a simple visual stimulus – a large letter made of small letters. This compound figure, as it is called, could be either congruent or incongruent on both global and local levels. Simply speaking, the large letter could be of the same type as the small ones that formed it or the large letter and small letters might be of two different types. The task for participants is very simple: focus attention on one level (e.g., large letter) while ignoring the other one and indicate which type the target letter is. Navon discovered two things; firstly the processing of the global letter was faster and better (less errors) than the local letters and the processing of the global level was unchanged, regardless of the letter from this level being congruent or incongruent with that from the local one. Secondly, when processing the local level, the difference between congruent and incongruent conditions occurred and was to disadvantage of the latter one. Navon concluded that his study demonstrated that visual perception can be characterized by global advantage effect. This effect consists of two elements represented by the above-mentioned results; namely global precedence (the whole is processed faster than its parts) and global interference (incongruent feature from the global level affects processing at the local level but not vice versa).

Since then, many studies have been carried out allowing for the determination of the specific characteristics and limitations of global processing (see Kimchi, 1992; Navon 2003). Is the Navon effect really an example of ventral stream functioning? Firstly, visual grouping by Gestalt laws is said to be in the domain of the ventral stream (see Goodale and Milner, 1995). The global advantage refers to holistic processing and this is why it is often treated as being Gestalt in nature. Secondly, as local forms in vision are processed by the primary visual cortex (see Braddick et al., 2003), the integration of complex patterns, which leads to the perception of global structure, takes place in the ventral stream and should start in area V4 which is a part of ventral pathway (Badcock and Clifford, 2004; Wilson and Wilkinson, 1998). Therefore, it seems to be reasonable to claim that global precedence and global interference might be treated as the results of the functioning of the ventral stream.

Vision for action and the functioning of the dorsal stream is represented in the present study by the affordances effect, as was demonstrated by Tucker and Ellis (1998). Although scientist still dispute what is really meant by affordances (see Chemero, 2003; Michaels 2003) in a broad sense, it can be said that they are visual information about certain objects that inform 'directly' an organism about what motor actions might be acted upon this object. Thus, one seeing a coffee mug on his/her desk is instantly prepared (without awareness) to grasp the mug in an appropriate way; that is, by its handle. Handle "graspability" is the affordance of the coffee mug. In an experiment by Tucker and Ellis (1998) participants were presented with pictures of everyday objects that could be either in an upright or in an upside down position and could had their handles orientated either leftwards or rightwards. The task for the participants was to indicate by pressing buttons with their right or left hand whether the seen object was in a normal or an inverted position. The instructions given said nothing about handle orientations. Tucker and Ellis showed that subjects responded faster and more accurately with the hand on the side towards which the handle of the presented object was orientated. According to the authors, this result demonstrates that visual information about a seen object generates and enhances certain motor actions that can be performed on these objects even without an intention to act upon it. In this case, orientations of graspable handles (to the left or to the right) afforded movements of left or right hand respectively. Affordances were also demonstrated with methods other than behavioural ones. Grèzes and Decety (2002) were able to demonstrate with the PET method that regions which are part of the dorsal stream are also activated when one looks at some objects and does not perform any action on them nor has any intention to do so. The authors conclude that motor representations of seen objects are present even though there are no actual visually guided movements related to that objects. In addition, Valyear et al. (2006), using the fMRI technique, demonstrated that the functioning of the dorsal stream was associated with the visual control of actions directed to seen objects. Rizzolatti and co-workers (1997), and Fagg and Arbib (1998), suggest that the cortex regions AIP and F5, which belong to the dorsal stream in the brain, are responsible for extracting possible affordances from objects in view. Affordances are then connected to the functioning of the dorsal stream and are examples of vision-for-action.

The aim of the current study is to explore the relations between vision-for-perception and vision-for-action by combining global precedence effect and the affordance effect in one task. These two effects representing the two functions of vision and revealed by two elegant paradigms of behavioural studies, appear to create a great opportunity for studying potential interactions between the two aspects of vision. In order to achieve this goal, a compound figure is generated that hierarchically (i.e., on both the global and local level) organizes objects with features capable of eliciting affordances. These affordances might be either consistent or inconsistent between two levels. Such stimulus provides the conditions for the occurrence of Navon as well as the affordance effect simultaneously.

Two possible outcomes are considered; if the combination of these two effects works similarly as in experiments with 'grasping visual illusions' the two effects should occur simultaneously without any infiuence on each other. This would support the hypothesis regarding the functional separation of the two systems for vision. Alternatively, if the planned imposition of Navon and the affordance effects allows potential interaction between vision for perception and vision for action to be tracked – then the following situations are possible. Firstly, both effects influence each other, hence they both occur, although in slightly changed form (e.g., they will be inverted), or they will both cancel themselves – each effect will disappear. Another case might be that one effect affects the other one – in that condition one effect will have its normal form while the other will have a different form. This type of result would help to determine, to some extent, the possible directions and degree of interactions between vision for perception and vision for action - the interactions that are not provided for by the theory of Milner and Goodale. The study is aimed at verifying the hypothesis stated above.

Experiment 1

Method

Participants. Thirty-four participants took part in Experiment 1 (17 women and 17 men, mean age was 21.32, age ranged from 19 to 28). All participants were students from the Warsaw School of Social Sciences and Humanities campus in Wrocław. Students participated in Experiment 1 for credit points or as volunteers at the experimenter's request. All had normal or corrected to normal vision and were naïve regarding the purpose of the experiment.

Apparatus and stimuli.

The experiment was run on a PC computer with a 21" LCD monitor (60 Hz refreshing rate). Program E-Prime 2.0 Professional® was used for presenting all instructions, stimuli, and recording reaction times and correct answers. During the experiment participants sat alone in front of the computer in a darkened room. The distance between the screen and the face was approximately 80cm. The hierarchically organized figure (compound stimuli) employed in Experiment 1 was prepared by the experimenter for the purposes of this experiment. An example of a stimulus is shown in Figure 1.

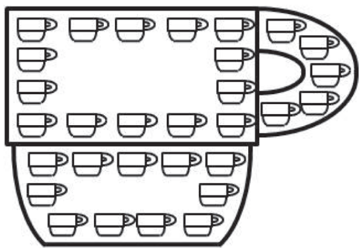


Figure 1. Compound figure used in Experiment 1 and 2. This example stimulus shows a case of congruency between levels. On both global and local levels (large and small cups), cup handles are orientated rightwards and both large and small cups are in the upright position.

The stimulus was a two-dimensional drawing of a large cup comprised of 30 little cups. The large cup (global level) was app. 13.05° x 9.6° of visual angle in size and the little ones (local level) were app. 1.5° x 1.3°. Each cup on each level (global or local) could have their grasp handle orientated either leftwards or rightwards. At the same time, each cup on each level could be in one of two possible positions: normal or upside down. This means that the combination of all these conditions gives 16 types of compound stimuli with different pairs of consistency, either of orientation or of position. The full list of all types of compound stimuli can be found in the Appendix.

The cup, as the graspable object employed in this experiment, was introduced for practical reasons, i.e., it was easier to design a responding device for such an object. The compound stimuli used in this study have one additional characteristic that objects used in other studies were lacking. The large figure (a cup at the global level) has its own contour, making it a distinctive object on its own. Such manipulation of compound stimuli is not entirely in line with suggestions about what the hierarchical organized figure should look like (see Kimchi, 1992; Navon, 2003). The reasons for the introduction of such an alternation was to ensure that the global figure would be clearly distinguished and independent of its local parts and would be a single autonomous object with its own self-containing affordance.

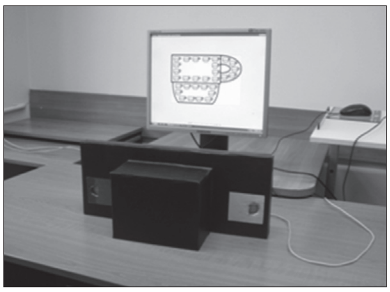
Because of the outline of the shape of the global cup, it was assumed that its representation would be enhanced and so would be its affordance. A final argument in favour of using a large figure with its own contour is that compound stimuli designed in this manner resemble objects from real life, where some complex things with many parts may have one affordance for the whole object, and many other affordances connected with its small parts.

Procedure.

Experiment 1 used repeated measure design within subjects. All participants went through 4 blocks, run in a random order; each block consisted of training (16 trials) and a testing phase. In the testing phase, all 16 types of compound figures were randomly shown 8 times which gives 128 trials per block. There was one general instruction displayed on the screen before the whole experiment that explained to the participant the procedure they should follow. Their task was to indicate with the right or the left hand whether a particular object – a large or a small cup – was in a normal or an upside down position. Participants were asked to work as fast and as accurately as possible. Before each block, precise instructions were given with detailed information about the task and the proper response to it. Every instruction remained on the screen as long as each of the participants wanted it. The instruction for the particular task was to look either at the position of a large cup or at the position of a little one. Target objects were assigned colours depending on the task condition (i.e. "If a large figure is an object in a normal position please press red, if it is upside down please press green"). There were two types of answer mappings – either the left hand response was assigned for the normal and the right hand response for the upside down position of the cup at a particular level, or it was assigned the other way round – the left hand response for the upside down position and the right hand response for the normal one. Response-to-hand mappings were counterbalanced. This combination of two levels and two types of response gives 4 task kinds, and 4 blocks respectively.

Participants gave their responses with their index fingers using a special 'black box', a device especially made by the experimenter for this experiment (see Figure 2).

A



B

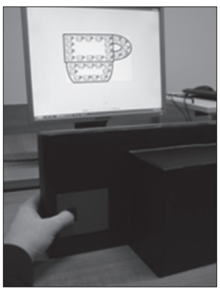


Figure 2.A. Device response (the "black box") used in Experiment 1 and 2. B. Left hand position when responding with the "black box".

In a cardboard box pasted over with matt black paper, a standard QWERTY keyboard was hidden of which the participants were unaware. The keyboard in the box was in a vertical position with its upper side (buttons) facing the computer screen. Hence, the keys were on the opposite side of the box from the point of view of the participant. Semi-circular holes were cut on both far ends of the box in the front and back. At the back of the box, the holes were in locations were the keys '~' and '-'are, on the far left and far right respectively. The holes were positioned so the participant could comfortably lay their hands on the table and put their index fingers (finger of the left hand on the left side, right hand finger on the right) into the holes at the back of the box and their thumbs into the holes on the front side of the' black box'. While keeping both fingers of both hands in the holes, the buttons could be pressed by small movements of the index fingers. Participants kept their fingers in the holes throughout the whole experiment. Above each hole in the front of a box, a small colour sticker was affixed – red on the left side and green on the right. The stickers marked the answer buttons. The alignment of the fingers in the holes was intended to mimic the type of hand movement needed for holding a cup by its handle. According to the literature (Craighero et al., 1999), keeping the hand in a certain position is associated with the preparation of a certain movement in advance, which in turn infiuences the perception of the affordances of the viewed object related to that movement. Thus, it is thought that the hand position applied in this experiment will enhance affordances.

Participants were asked not to cross their hands, nor to turn the 'black box' around. Each trial consisted of a sequence of the following events. First, for 700ms a fixation point (a little black cross in the middle of the white background) was shown. Next, the compound stimuli were shown. The stimuli remained on the screen until the participant gave his/her response or until 1500ms had passed. If the participant responded in a specified time, the feedback information was displayed on a white background. All feedback information was displayed in black ink. If the participant did not respond in a given time, a message saying 'no answer' was shown. The information about performance stayed on the screen for 1000ms. After that, a new trial started.

Results

As was mentioned above, there were actually two kinds of incongruence between the objects from the global and local levels within the 16 types of compound stimuli used in Experiment 1. In particular, large and small cups could differ between levels either with their position (upward or inverted) or with handle orientation (leftward or rightward). Object position factor was one that was relevant for the participants' task, who as subjects had to decide whether the cup at a particular level is in normal or upside down position. However, this factor is irrelevant for the affordances problem studied here. Thus, the only cases taken into account for analysis are those when there is only one type of incongruence - namely that of handle orientations. Therefore, in the following analysis only data from these trials from Experiment 1 were included where the following types of compound stimuli were presented (according to the list from the Appendix): 1-4 and 9-12. It needs to be emphasised that due to the task demands of Experiment 1, the incongruence that is being analysed here refers to that stimulus feature which participants did not direct their attention towards.

Before running the analysis results for RTs, the accuracy rates were tested (with K-S test) to check if they were normally distributed. It turned out that in the case of accuracy results they were not normally distributed (p=.05). There was a "ceiling effect" – almost all the participants achieved relatively high scores (app. 95%). Because of this, results for accuracy rates were not included in the analysis.

Table 1. Means and standard deviations for reaction times and accuracy for 16 conditions of data analysis from Experiment 1.

Condition	Reaction times (milliseconds)		Accuracy (percentage of correct responses)	
	mean	SD	mean	SD
Global level, Left hand, Leftward handle orientation, Congruence of handle orientations	527.11	66.83	0.97	0.054
Global level, Left hand, Leftward handle orientation, Incongruence of handle orientations	513.79	72.18	0.96	0.058
Global level, Left hand, Rightward handle orientation, Congruence of handle orientations	534.77	76.51	0.96	0.062
Global level, Left hand, Rightward handle orientation, Incongruence of handle orientations	538.72	77.26	0.96	0.078
Global level, Right hand, Leftward handle orientation, Congruence of handle orientations	536.80	80.55	0.95	0.064
Global level, Right hand, Leftward handle orientation, Incongruence of handle orientations	530.16	75.48	0.94	0.090
Global level, Right hand, Rightward handle orientation, Congruence of handle orientations	507.86	66.70	0.97	0.044
Global level, Right hand, Rightward handle orientation, Incongruence of handle orientations	514.22	75.59	0.98	0.045
Local level, Left hand, Leftward handle orientation, Congruence of handle orientations	580.41	71.27	0.97	0.072
Local level, Left hand, Leftward handle orientation, Incongruence of handle orientations	577.46	61.36	0.98	0.062
Local level, Left hand, Rightward handle orientation, Congruence of handle orientations	582.95	77.34	0.96	0.045
Local level, Left hand, Rightward handle orientation, Incongruence of handle orientations	588.09	73.36	0.97	0.079
Local level, Right hand, Leftward handle orientation, Congruence of handle orientations	594.57	80.54	0.97	0.054
Local level, Right hand, Leftward handle orientation, Incongruence of handle orientations	606.69	74.67	0.97	0.052
Local level, Right hand, Rightward handle orientation, Congruence of handle orientations	572.16	71.89	0.98	0.048
Local level, Right hand, Rightward handle orientation, Incongruence of handle orientations	582.79	72.30	0.98	0.069

For all conditions N=34

Means for reaction times (RTs) from selected conditions (see above) of all the participants were submitted to repeated measure ANOVA within participants. There were four independent variables with each having two levels, which gives 16 experimental conditions all exercised by every participant. These variables were as follows: Level at which target object was located (global vs. local), Hand of Response (left vs. right), Handle Orientation of target object (left vs. right) and Congruency between global and local level handles orientation (congruent vs. incongruent).

Response time. There was main effect of Level, $F(1,33)=44.511$, MSE=11078.13, $p<.001$, $\eta 2=.57$, that is participants were faster when responding to target stimuli from the global level compared with responses to stimuli from the local level. ANOVA revealed also two interactions. One was an almost significant interaction between the Level and Hand of Response, $F(1,33)=4.092$, MSE=1439.67, $p=.051$, $\eta 2=.11$. When answering at the global level participants were faster than at the local level. At the global level, the right hand responses were slightly quicker than responses with the left hand. At the local level, this was reversed, although these differences between the responses of hands at each level were not significant as the post hoc analysis revealed (see Fig. 3). Basically, this interaction re ects the described above effect of the Level factor.

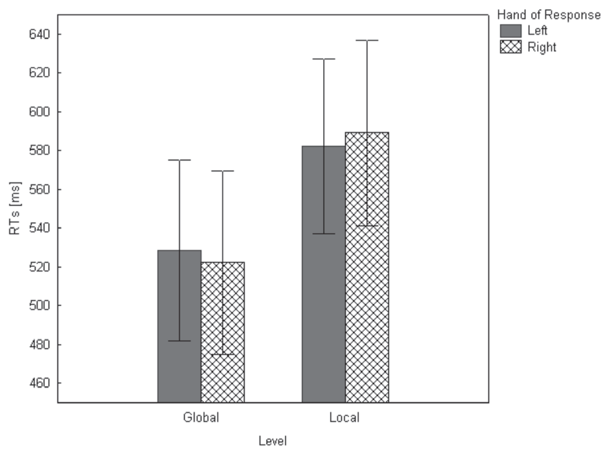


Figure 3. Interaction between the Level and the Hand of Response for mean reactions times ($F(1,33)=4.092$, $p=0.051$) from Experiment 1.

The second interaction was between Hand of Response and Handle Orientation, $F(1,33)=21.78$, MSE=1829.9, $p<.001$, $\eta 2=.40$, demonstrating the typical affordance effect – when the hand of response matched the orientation of the cup handle, responses were faster compared to situations where there was no such correspondence (Fig. 4). Responses with the right hand were faster than those with the left hand when the object had its handle orientated rightwards; left hand responses were faster than right ones when the target object handle was orientated leftwards. This is the so-called affordances effect – the unattended visual feature of the object triggers motor responses corresponding with that aspect of the seen object.

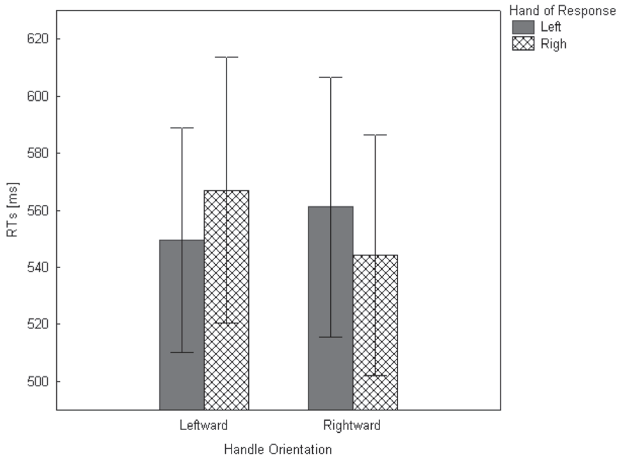


Figure 4. Interaction between the Handle Orientation and the Hand of Response for mean reaction times ($F(1,33)=21.78$, $p< .001$) from Experiment 1.

Discussion

Firstly, it should be highlighted that Experiment 1 revealed very robust affordance effects similar to that of Tucker and Ellis (1998). When participants saw drawings of the cup with its handle orientated toward a particular side, the hand on that side was more quickly prepared to perform motor action, even though the task was not to make a quick response in relation to handle orientation. Unattended (to some extent) features of the seen objects afford certain actions, even though these actions are unintended. This gives support to the claim that affordances are real phenomenon. Vision of an object contains necessary information needed for motor actions that is processed directly, though in parallel manner, with the processing of information about the identity of the object. This particular effect of Experiment 1 demonstrates the function of vision for action - when watching a graspable object the features that relate to motor actions (that can be acted upon that object) infiuence movements of the person observing that object, even though these features are not consciously attended. Of course, in Experiment 1 affordances were enhanced by a particular hand position while responding. This was the utilisation of a mechanism in which motor actions in turn affect the mechanism of perception. The experimental manipulation was thus effective.

Considering vision for perception, the methods used here were thought to enhance and elicit the Navon effect but this occurred only in a limited manner. Information from the global level was processed faster than that from the local one. This result indicates perceptual global precedence in perceptual processing as postulated by Navon (1977), which is assumed as an attribute of vision for perception. However, the second aspect of the advantage of global processing in visual perception namely, global interference was not found in Experiment 1. Perceptual incongruence between levels had no effect. Perceptual difference from the global level did not affect performance when the object at local level was attended and processed. In other words, perceptual information from the global level did not disrupt the processing of information from the local level when these two were incongruent.

In Experiment 1, there was no interference between affordances from different levels. The incongruence of the handles' orientation between levels did not affect the relation of the hand of response with the handle orientation. That is the orientation of the cup handle from the global level had no affect whatsoever on the reaction time of the hand of response when the participant was responding to the target at a local level. This means that in these conditions there was no interaction between vision for perception and vision for action represented by the Navon effect and the affordances effects.

Therefore, although Experiment 1 managed to elicit and demonstrate the affordance effect and perceptual global precedence, it failed to obtain perceptual and affordances interference. One potential element responsible for this might be a factor of directing attention to particular features of seen objects. The next experiment was developed to verify this claim.

Experiment 2

This experiment was set up to test whether perceptual global interference and interference of affordances between levels would occur in a situation, when visual attention is directed to object features that are responsible for incongruence within a compound figure. In other words, interference should occur within a hierarchically organised figure, when there is only one kind of inconsistency and elements of the compound object in view related to that inconsistency are in the focus of attention. In the previous experiment, there were two types of incongruence namely the position of the cup and handle orientation and participants directed their attention to the first element (cup position – upright or inverted). Here, global and local objects could differ only with handle orientation (i.e. affordance element) and the subject's task was to focus their attention on that particular feature.

Method

Participants. Thirty-four participants took part in the Experiment 2 (17 women and 17 men, mean age was 21.85, age ranged from 19 to 31). All participants were students from Warsaw School of Social Sciences and Humanities campus in Wrocław or their friends. Students participated in the experiment for credit points or as volunteers at the experimenters' request. All had normal or corrected to normal vision and were not informed about the purpose of the experiment. None of the participants had taken part in the previous experiment.

Apparatus and stimuli. These were exactly the same as in Experiment 1, except for the number of types of compound stimuli (see Appendix). In this experiment only 4 types were used; those where cups that on both levels were in the upright position and they could differ between levels only by the handles' orientation. In other words, incongruence in the hierarchically organized figure is limited now only to the difference of affordances (different cup handle orientations, whereas the cup position is always normal). In Experiment 2, stimuli with numbers 1 to 4 from the list of stimuli types from the Appendix were used.

Procedure. There was a new kind of task in Experiment 2. Now participants were asked not about the position of a cup at a certain level but were instructed to indicate whether a cup at a particular level had its handle orientated left or right. They were asked to do that by pressing either the red button in the 'black box' or the green one. There were 4 blocks (two levels which participants should attend and two types of key assignment). Each block consisted of 44 trials (every type of compound figure was repeated 11 times in random order).

Results

Data processing and analysis were in all respects identical to the previous experiment. Once more, in the case of accuracy rates results the "ceiling effect" occurred. Because of this, these results were not taken into account in analysis.

Response times. Two main effects were significant. There was the main effect of Level, $F(1,33)=165.636$, MSE=7552.58, $p<.001$, $\eta 2=.83$, participants were faster in their responses when answering stimulus from the global level. This indicates the global precedence effect. There was also the main effect of the congruency of handles orientation between levels, $F(1,33)=31.881$, MSE=1137.30, $p<.001$, $\eta 2=.49$. Responses times were shorter when there was a congruency compared with the situation when there was no consistency of cup handles between levels. There were also three signi cant interactions. The first one was that of the Hand of response and Handle Orientation, $F(1,33)=83.508$, MSE=11764.94, $p<.001$, $\eta 2=.72$ (presented in Fig. 5), which demonstrates the affordance effect when the response is faster if orientation of the cup handle corresponds to the hand of response.

The second interaction was between the Level and Congruency of the cup handles' orientation between levels, $F(1,33)=29.741$, MSE=1131.36, $p<.001$, $\eta 2=.47$, this interaction is shown in Figure 6. Participants were faster when responding to the global level than to the local one and the response rates were comparable in cases whether or not there was a congruency of cup handles. With reaction times at the local level, however, the congruency of cup handles differentiated results. In the cases with incongruent handles, response times were much longer than those

Table 2. Means and standard deviations for reaction times and accuracy for 16 conditions of data analysis from Experiment 2.

Condition	Reaction times (milliseconds)		Accuracy (percentage of correct responses)	
	mean	SD	mean	SD
Global level, Left hand, Leftward handle orientation, Congruence of handle orientations	396.93	65.08	0.97	0.041
Global level, Left hand, Leftward handle orientation, Incongruence of handle orientations	395.00	59.42	0.99	0.026
Global level, Left hand, Rightward handle orientation, Congruence of handle orientations	469.30	103.99	0.97	0.073
Global level, Left hand, Rightward handle orientation, Incongruence of handle orientations	472.96	92.53	0.96	0.106
Global level, Right hand, Leftward handle orientation, Congruence of handle orientations	461.18	103.99	0.97	0.057
Global level, Right hand, Leftward handle orientation, Incongruence of handle orientations	464.08	90.08	0.97	0.074
Global level, Right hand, Rightward handle orientation, Congruence of handle orientations	393.26	57.20	0.99	0.022
Global level, Right hand, Rightward handle orientation, Incongruence of handle orientations	391.02	48.51	0.99	0.037
Local level, Left hand, Leftward handle orientation, Congruence of handle orientations	458.94	81.18	1	0
Local level, Left hand, Leftward handle orientation, Incongruence of handle orientations	497.32	82.69	0.95	0.174
Local level, Left hand, Rightward handle orientation, Congruence of handle orientations	553.47	106.03	0.95	0.087
Local level, Left hand, Rightward handle orientation, Incongruence of handle orientations	586.17	102.20	0.86	0.206
Local level, Right hand, Leftward handle orientation, Congruence of handle orientations	564.97	106.96	0.96	0.073
Local level, Right hand, Leftward handle orientation, Incongruence of handle orientations	595.22	102.24	0.89	0.201
Local level, Right hand, Rightward handle orientation, Congruence of handle orientations	464.01	88.30	0.99	0.037
Local level, Right hand, Rightward handle orientation, Incongruence of handle orientations	490.91	74.43	0.95	0.168

For all conditions N=34

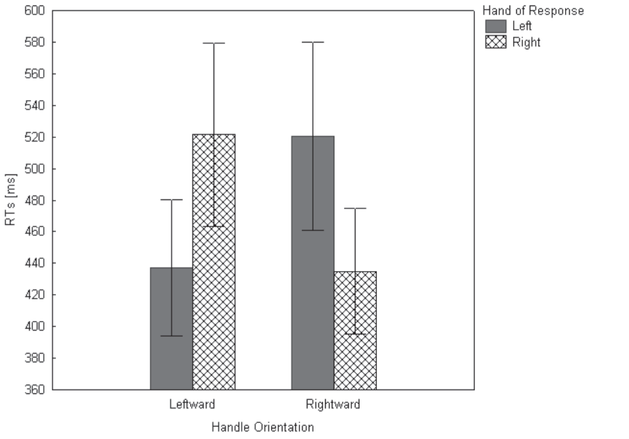


Figure 5. Interaction between the Handle Orientation and the Hand of Response for mean reaction times ($F(1,33)=83.508$, $p< .001$) from Experiment 2.

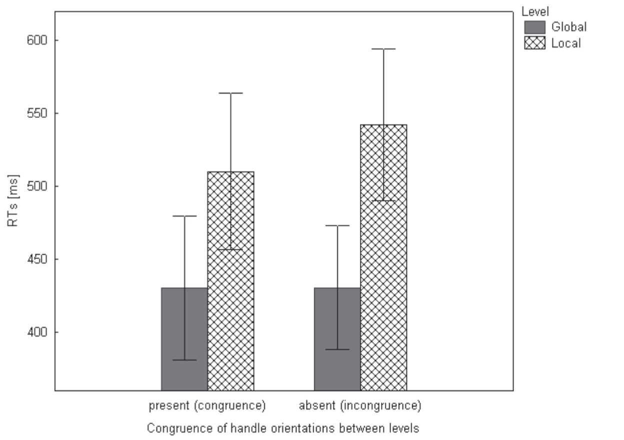


Figure 6. Interaction between the Level and the Congruency of the cup handles' orientation between levels ($F(1,33)=29.741$, $p< .001$) from Experiment 2.

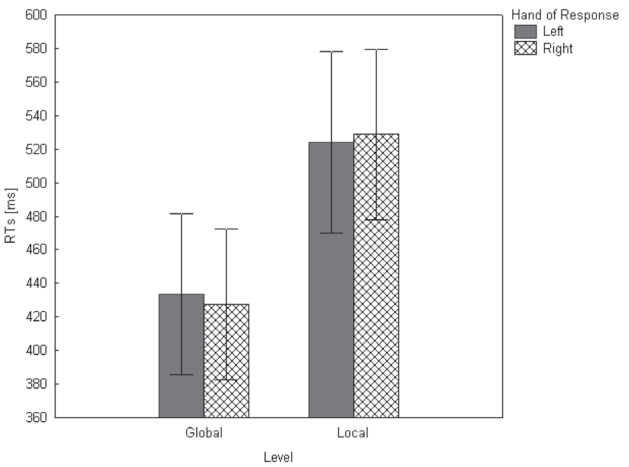


Figure 7. Interaction between the Level and the Hand of Response for mean reaction times ($F(1,33)=4.703$, $p< .05$) from Experiment 2.

with congruent handles. This interaction demonstrates the perceptual global interference effect.

The third interaction was between the Level and the Hand of response, $F(1,33)=4.703$, MSE=869.279, $p<.05$, $\eta2=.12$, reaction times for both hands were faster at the global level than at the local one (see Fig. 7). When giving their responses at the global level participants were slightly faster with their right hands than with their left hands, at the local level this was reversed, though these differences between the hands of response were not significant as post hoc analysis revealed.

Discussion

Navon's effect – the advantage in processing of perceptual global information – was revealed (with RTs results). This means that apart from global precedence global interference was also demonstrated. Perceptual information from the global level, if different from that from the local level, distorted the processing of the latter. Experimental manipulation was effective. The limitation of incongruence types in compound stimuli and directing attention straight to the features of hierarchically organised stimuli, which may generate inconsistency within these stimuli, allowed the robust effect of perceptual global advantage to be demonstrated.

RTs in Experiment 2 showed the affordances effect, in which particular visual information (in this case the orientation of the cup handle) enhanced certain motor reaction (here response with the hand corresponding to the handle orientation) related to that feature of the seen object. One may object that in the experiment described above the effect obtained was not exactly the same as that of Tucker and Ellis (1998) because here participants directly attended and processed with awareness those features of seen objects that were responsible for eliciting affordances. However, it seems to be reasonable to think that such processing of visual information does not exclude or reject the possibility of affordance to operate. Affordances of course are understood in this way - that some features of seen objects enhance motor actions related to these features without the conscious processing of this relation. However, the results obtained in this experiment (where participants looked directly at the handles orientation and used that information for task solving only) confirm the stance that the brain uses visual information for the preparation of particular movements. This is the case because the participants did not realize that the main purpose of the task was to measure whether a particular object orientation may make movements with the corresponding hands quicker. Thus, in our opinion the affordance effect from the Experiment 2, although not entirely in line with the paradigm of Tucker and Ellis, can be accepted as an example of mechanisms of vision for action.

Most important of all is that while these two effects (global advantage and affordances) are present, there is no interaction between them. Perceptual global advantage does not affect affordance processing and vice versa. It seems to be sensible to put forward a claim that these two effects are independent of each other. This is also supported by the results from the previous experiment. Perceptual global advantage and affordance effects seem neither to interfere nor cooperate and they do not lead to the emergence of any additional or new effect. One needs to bear in mind, however, that the separation of vision for perception and vision for action, as represented by these two effects, takes place in a particular condition of strengthening the effect of affordances through positioning the hands in a specific manner and preparing them for specific movements which reciprocally affects the processing of visual information.

It appears that the crucial factor for the occurrence of global interference is directing attention to these features of objects creating compound stimuli that are strictly connected to possible inconsistency within those compound stimuli. Thus, before moving to a general discussion of conclusions that can be drawn from the results of this study, one additional analysis need to be considered.

Supplementary analysis of data from Experiment 1

In Experiment 2, where there was only one type of incongruence within compound stimuli (i.e., handles orientation), and the participants directed their attention to that object characteristic, the data analysis revealed the full Navon effect – both global precedence and global interference occurred. However, analysis of selected cases from Experiment 1, where the only incongruence present was that of the handles' orientation but participants directed their attention to other features of the observed objects, showed that the perceptual effect of global advantage did not occur. Thus, the following analysis is aimed to see whether the perceptual effect of global advantage shows up when only these cases from Experiment 1 are taken into account where the only incongruence is the one to which participants devoted their attention, namely inconsistency related to the position of objects (upright or inverted)

According to the list of types of compound stimuli from the Appendix for the following analysis of trials from Experiment 1, stimuli with odd numbers from that list were selected. In all these cases of compound stimuli only one type of incongruence is possible – that of position of the cup (normal or upside down). Orientation of handles on both levels is always the same. Additionally in this analysis, only two independent variables were considered because only their interaction demonstrates the full Navon effect. These variables were the Level of directing attention (global or local) and the Congruency of cup position between levels (present or absent).

RTs data from selected trials were submitted to two-way ANOVA.

Results

Response times. All main effects and the interaction were significant. There was the main effect of Level, $F(1,33)=78.421$, $MSE=2507.42$, $p<.001$, $\eta 2=.7$, showing that participants were faster when responding to objects at the global level. This is the global precedence effect. The main effect of Congruence was significant $F(1,33)=28.118$, $MSE=544.19$, $p<.001$, $\eta 2=.46$, and showed that participants were faster with their responses when there was a congruency of cup position between levels compared to the

Table 3. Means and standard deviations for reaction times and accuracy for 4 conditions of supplementary analysis of data from Experiment 1.

	Reaction times (milliseconds)		Accuracy (percentage of correct responses)	
	mean	SD	mean	SD
Global level, Congruence of cup positions	526.66	66.85	0.96	0.043
Global level, Incongruence of cup positions	527.60	63.39	0.96	0.041
Local level, Congruence of cup positions	582.43	68.16	0.97	0.045
Local level, Incongruence of cup positions	623.92	57.67	0.95	0.059

For all conditions N=34

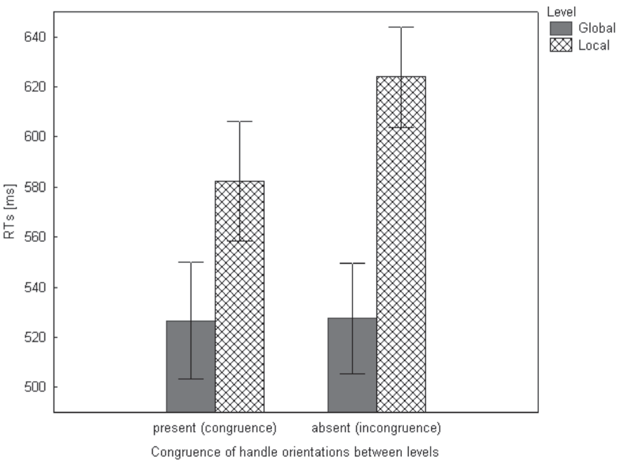


Figure 8. Interaction between the Level and the Congruency of the cup's position between levels for mean reaction times ($F(1,33)=33.608$, $p< .001$) from supplementary data analysis from Experiment 1.

situation when such congruency was absent. There was also the interaction of Level and Congruency, $F(1,33)=33.608$, MSE=415.87, $p<.001$, $\eta2=.5$ (see Fig. 8). The pattern of results evidently demonstrates the full Navon effect – global precedence and global interference.

Discussion

Even though the revealed effects only come from RTs measures, the results of the above analysis along with the results from previous experiments support the claim stated earlier. This is the full perceptual global advantage effect consisting of global precedence and global interference occurs only when attention is directed to the features of objects creating the compound stimuli, which features are responsible for possible perceptual inconsistency within that hierarchically organized figure and no other incongruence is present. At the same time, this result suggests that the perceptual global advantage effect might not be located at the early stages of perceptual processing, as was postulated in literature on that topic (e.g. Kimchi, 1992). This will be discussed in more details in the final remarks below.

General discussion

The conducted experiments provided results that together present a reasonably coherent picture, showing that there is no interaction between vision-for-perception and vision-for-action, at least in the particular case of the imposition of two effects representing these two visual functions. There is no interaction between global advantage, consisting of global precedence and global interference, with the affordance effect in conditions when the particular hand movement relating to that affordance is pre-programmed by certain finger alignments. These two effects in this setting seem to occur separately without any clear and overt mutual influence. Let us first in turn discuss the occurrence of these effects on their own in the experiments described above.

In both experiments the affordances effect did occur. This means that the observed objects and their features enhanced particular motor actions that could act on these objects. It happened both when participants directly focused their attention on the attributes of objects that were responsible for eliciting affordances (Experiment 2), and more importantly, when participants' attention was directed to other features of these objects (Experiment 1). Thus, these results lend support to the notion that the method introduced by Tucker and Ellis (1998) is an effective and valid way of testing affordances. The obtained results also support the idea that affordances exist in the real world – objects in view automatically (without conscious awareness) activate and strengthen the motor actions that can be performed on that objects. The visual system treated as a whole, while processing information needed for recognition of seen objects, simultaneously and in parallel extracts data required for the preparation of motor programme (i.e., how to interact with those objects). In other words, the results of the experiments discussed above demonstrate vision-for-action 'in action'.

It is worthwhile to draw attention to the fact that the affordances effects were obtained in the described experiments by the employment of two-dimensional drawings of objects. In the literature, it is suggested that photos are usually better for attaining affordances effects than drawings (e.g., Hibi and Yokosawa, 2007) or that if drawings are used, they should at least generate an impression of depth (Symes et al., 2007). It is possible, however, that affordances effects were obtained here with 2D drawings because they were constantly reinforced by the hand position while participants gave responses. This issue of the fingers' alignment will be brought up again below, when dealing with the lack of interaction between the effects of global advantage and affordances.

When discussing the second effect, global perceptual processing, which is thought to be an example of the functioning of vision-for-perception, the results of the experiments performed do not provide such clear-cut conclusions as with the affordances effect. In all cases, there was an effect of global precedence – perceptual information from the global level of compound stimuli was processed faster than information from the local level. The full Navon effect, i.e., the situation where processing of local level information is impaired by global level information, occurred only in specific conditions. In particular, it was only present when participants' attention was overtly directed to these features of objects building up hierarchically organized stimuli that were directly connected to the possible incongruence within the compound figure. When participants were not focusing their attention on the aspects that were related to consistency or inconsistency of compound stimulus, then the global interference effect disappeared. Therefore, the collected results strongly support the conclusion that, in order to obtain global interference effect, attention needs to be overtly orientated toward these aspects of the compound figure which determine congruency or incongruency within this kind of stimulus. This conclusion is somewhat in line with the results of the experiments by Paquet and Merikle (1988). These researchers showed that the processing of global information, which comes from objects presented near the object at the global level of compound stimulus, is limited when this information falls beyond the attention of the perceiving subjects. Although they used different methods compared to that employed in the presented experiments, it seems reasonable to state that the perceptual global interference effect probably requires conscious processing of aspects of the compound figure's inconsistency, or at least directing overt attention to them. This in turn may indicate however, that global interference effect cannot be located at the early stages of perceptual processing. This is in contrast to conclusions drawn by Miller and Navon (2002), based on their study using EEG, in which researchers claimed they managed to demonstrate that lateralized readiness potentials (LRP), related to the preparation of hand movements, are evoked by the stimulus assigned to it, presented at the global level but not by stimuli from the local level. Authors interpreted their results in this way that part of the global processing occurs before the reaction is prepared and thus it suggests that global advantage is generated at the early stages of perceptual processing. Alternatively, it may be that this connection is mediated by the factor of orientation of attention. It is possible that when the participants' attention were directed to features of compound stimuli that were not related to inconsistency within this stimuli, the relationship between LRP and global information might not appear and it might be impossible to generate such an assignment. This research did not make it possible to determine whether it is attention that plays a crucial role in this problem, and it seems legitimate to combine the method of Miller and Navon with that of this experiment, in order to further explore the issue of where exactly in perceptual processing the global advantage takes place.

The most important result of the conducted research demonstrates that even if the effect of global interference does turn up in particular conditions, it has no apparent influence on affordances effects. That is when hierarchically organized stimuli are presented and have different affordances at different levels, and these features are simultaneously aspects of the compound stimuli that constitute its incongruence (which causes in turn perceptual global interference) no interaction of affordances occurs. This means that such condition does not induce the affordance from global level to interfere with the processing of affordance from the local level. It seemed reasonable to assume that if the coexistence of affordances, demonstrated in other studies (see below), leads to their interference (i.e. impairment of the processing of activated affordance by other affordance presented simultaneously) then in the case when some perceptual mechanism like the Navon effect, imposes aspects of viewed objects on each other, this also will impose affordances and thus will cause distortion in their processing. The results obtained, however, showed that this was not the case and that this expectation was not justified.

As mentioned before, several researchers demonstrated the interference between affordances being presented at once, which corresponds to situations from the real world. Furthermore, such interference was also shown to exist between the global and local level. Vainio et al. (2007) provided evidence that ignored affordance from the global level affects that from the local level. This occurs, however, only when these two affordances are components of one meaningful object. Hence, the shape of an apple as an affordance influences one's motor action when grasping the attached apple's stalk. Even though there is interference between affordances from different levels, it is clear that in experiments described in this paper the situation is definitely different. As is pointed out by Gentilucci (2002), in the case of the apple and its stalk, there are two affordances and thus two potential motor actions but they relate to the same individual object. In the experiments presented here, the global cup and local cups were different objects and the affordances of these cups did not belong to one unitary object, but to distinct and separable objects. Hence, it seems to be sensible to refer rather to experiments where interference between affordances was demonstrated with independent objects presented at the same time, when one object was the target and the other one was the distractor. The basic question is why other researchers managed to capture interference between affordances in their studies while in our experiments this effect did not occur.

It seems that two factors may a play role. The first one is attention[1]. It is noted (Tipper et al., 1997; Ellis et al., 2007) that interference between affordances of the target object and the distractor occurs most rarely when the observer's attention is focused on the target object and the motor action related to this target object's affordance is acted on. It means that, when someone is not dividing their attention between different objects that have different affordances, and focuses only on one, which becomes the goal of one's action, it is very likely that only the affordance of this

[1] When discussing the problem of the lack of the Navon effect a few paragraphs earlier, attention was also mentioned but it was understood as object-based attention. Here, when talking about the lack of interference of affordances between levels of compound stimuli, space-based attention is called for and 'blamed'. It is interesting to ask whether this study, after some modifications, allows for exploring the idea that object-based and space-based attention are related to vision-for-perception and vision-for-action, respectively.

one object is processed and others are ignored, and there is no affordance interference. In the case of experiments described in this paper, participants focused their attention either on the global level or on the local one. In each case, one level was ignored. There was no divided attention. Thus, interaction of affordances was probably restricted.

One way to test the hypothesis that focused attention prevents affordances from interfering would be to employ the 'divided attention' paradigm because it allows the perceptual global advantage effect to be seen in compound stimuli processing (see for instance Miler and Navon, 2002). In contrast to the focused attention paradigm utilized in this experiment, in the divided attention condition the participant is asked to monitor both levels of the hierarchically organised stimulus so no one level is ignored. The task for participants this time is not to decide whether object on certain level is X or Y but whether a certain object (e.g., X) is present or not present - somewhere in the compound stimuli. Thereby, in the divided attention paradigm for perceptual global processing, the task has strictly the character of a visual search. As noted above in this case, perceptual global advantage (both global precedence and global interference) does occur. Hence, the hypothesis is that when processing compound stimuli, similar to the ones described in this paper, affordances would probably interfere in a condition of divided attention.

The second factor that could potentially have caused the lack of interference between global processing and affordances is a responding method, consisting in performance of certain motor action. Usually interference between different affordances is revealed if the participant needs to perform a movement of the whole hand (i.e., reaching) and not mere button pressing with fingers (e.g., Tipper et al., 1997). Additionally, reaching and grasping relates to visuo-motor processes other than simple pointing and/or pressing the button (see Pavese and Buxbaum, 2002). In the experiments presented above, participants did not reach and grasp cups; instead, they performed only button pressing although their fingers were shaped as if they were holding the cup by its handle. As it was mentioned earlier, the preparation of motor action influences detection and the discrimination of certain features of viewed objects (see Craighero et al., 1999). Thus, it is possible that this alignment of fingers could have reciprocally enhanced affordance of the cup handle and caused concurrent affordance to be unattended. Additionally, affordance enhancement combined with focused attention (on one level of compound stimulus only) resulted in the competing affordance being ignored. Although it poses some technical difficulties, it would be worthwhile to verify this hypothesis by conducting this experiment in a way that participants should respond by performing a whole movement (starting from a neutral resting position) of reaching and grasping, while attention conditions are being controlled. Perhaps in such a situation, when visually guided movement is generated on-line and there is no prepared and pre-programmed motor action, affordances of target objects and those of objects from another aspect of a compound stimulus would compete and cause interference.

The discussed alignment of fingers while responding, which potentially leads to enhancement of affordances, relates to another issue, a more theoretical one. One may reflect that actually, when someone looks at everyday familiar object and considers its effective grasping (i.e., grasping a cup by its handle) this is an example of interaction between the functioning of the ventral and dorsal streams (see Creem and Proffitt, 2001). Hence, as described in the above experiments, the imposing affordances effect (as looking at cups and their handles) and Navon effect would be in fact 'interaction in interaction' or interaction only within vision-for-perception (and then only within the ventral stream). Such case might occur because recognition of everyday objects is the effect of the ventral stream functioning as it is also perceptual global precedence. However, it seems reasonable to claim that hand positioning counterbalances this and allows the shift of these affordances used in these experiments back to vision-for-action functioning and resumes the distinction between ventral and dorsal processing. Nevertheless, probably a more accurate design with more sensitive measures is needed, which will clearly distinguish these functions and processes.

As demonstrated in this study, lack of interference between affordances from different levels of hierarchically organized stimuli suggests that processes of perceptual global advantage and processing of affordances are independent or separated. When someone looks at a graspable object and focuses his/her attention on it, potential motor actions that can be performed on that object are quickly extracted and activated. Simultaneously, when that object is a part of a larger whole that might be a subject of global processing, these processes are restricted only to perceptual operations and have no effect on visuo-motor performance. It seems that processes of vision for action (here extracting affordances) are faster than processes of vision for perception (here perceptual global advantage). This in turn confirms the assumption that the first is related to the functioning of the dorsal stream in the brain and the latter to that of the ventral stream, due to claims that neuronal performance of the dorsal stream in the brain is faster than that of the ventral stream (see Milner and Goodale, 1995). It should be borne in mind, however, that in this study, certain motor actions were pre-programmed and could have influenced the pace of visuo-motor processing, making it faster.

Results obtained in this study are in line with the theory of Milner and Goodale. It is important to emphasize, though, that certain theoretical considerations should not be misinterpreted. Hughes et al. (2005) state that global and local processing might influence dissociations between perception and action. Although their claim might not seem odd, it is rather inappropriate to interpret theory as they do by stating that global/local processing is something above or beyond the distinction between perception and action. Global/local processing is a perceptual characteristic and should be treated as such (and in empirical terms, this is what these researchers do). Furthermore, it is obvious that perception can modulate its relationship to action. However, the multiplication of possible explanations is unjustified.

The imposition of the Navon effect and the affordances effect was intended to study the potential interaction between vision-for-perception and vision-for-action, although it turned out that this method brings similar effects as studies using the technique of 'grasping of visual illusions'. Nonetheless, experiments from this study avoid some of the problems that experiments with illusions have faced. For example, it is not the case that there are two different tasks addressing two different functions of vision – perception and action. Hierarchically organised objects with their affordances appear to be good stimuli for demonstrating the separation of vision-for-perception and vision-for-action using behavioural measures. It would be interesting to further explore this case of the lack of interference of affordances in compound stimuli and verify it using techniques allowing it to be measured at the level of brain functioning.

Although the main result suggests independence between perceptual global processing and affordances processing, many factors from the present study suggest that an important role in the potential interaction between vision-for-perception and vision-for-action is played by visual attention. It seems that such interaction is not possible without attention. This notion however, requires further studies.

This independence or separation of affordance extraction from processes related to perceptual organisation seems to be reasonable. In the real world, many objects with many affordances surrounds us and these objects very often cluster and form groups. If the processes of perceptual organisation (like the Navon effect or perceptual Gestalt laws), apart from the arranging of visual information in order to form coherent internal representation, also leads to the combination of affordances of visually grouped objects, it is very likely that it would cause an overload in visual processing. Thus the fast and efficient performance on seen objects would be disabled. The separation of perceptual grouping from affordance extraction allows effective adaptation and visuo-motor interaction with the environment.

References:

Adamo, M., & Ferber, S. (2009). A picture says more than a thousand words: Behavioral and ERP evidence for attentional enhancements due to action affordances. Neuropsychologia, 47,1600-1608.

Aglioti, S., DeSouza, J. F. X., & Goodale, M. A. (1995). Size-contrast illusions deceive the eye but not the hand. Current Biology, 5,679-685.

Badcock, D. R., & Clifford, C. F. (2004). The inputs to global form detection. In: M. Jenkin & L. R. Harris (eds.), Seeing spatial form (pp.37-50), Oxford: Oxford University Press.

Braddick, O., Atkinson, J., & Wattam-Bell, J. (2003). Normal and anomalous development of visual motion processing: Motion coherence and 'dorsal-streamvulnerability'. Neuropsychologia, 41,1769-1784.

Brenner, E. , & Smeets, J. B. J. (1996). Size illusion in uences how we lift but not how we grasp object. Experimental Brain Research, 111,473-476.

Bridgeman, B., Perry, S., & Annad, S. (1997). Interaction of cognitive and sensorimotor maps of visual space. Percept Psychophys, 29,336-342.

Bruce, V., Green, P. R., & Georgsen, M. A. (2003). Visual perception. Physiology, psychology and ecology. (4th ed) Hove: Psychology Press.

Chemero, A. (2003). An outline of theory of affordances. Ecological Psychology, 15,181-195.

Craighero, L., Fadiga, L., Rizzolatti, G., & Umiltà, C. (1998). Visuomotor priming. Visual Cognition, 5,109-125.

Craighero, L., Fadiga, L., Rizzolatti, G., & Umilta, C. (1999). Action for perception. A motor-visual attentional effect. Journal of Experimental Psychology: Human Perception and Performance, 25,1673-1692.

Creem, S. H., & Proffitt, D. (2001). Grasping objects by their handles: a necessary interaction between cognition and action. Journal of Experimental Psychology: Human Perception and Performance, 27,218-228.

Culham, J. C., & Kanwisher, N. G. (2001). Neuroimaging of cognitive functions in human parietal cortex. Current Opinion in Neurobiology, 11,157-163.

Dougherty, R F., Ben-Shachar, M., Bammer, R., Brewer, A., & Wandell, B. A. (2005). Functional organization of human occipital-callosal ber tracts. Proceedings of the National Academy of Sciences: Biological Sciences, 102,7350-7355.

Ellis, R., Tucker, M., Symes, E., & Vainio, L. (2007). Does selecting one visual object from several require inhibition of the actions associated with nonselected objects? Journal of Experimental Psychology: Human Perception and Performance, 33,670-691.

Fagg, A. H., Arbib, M. A. (1998). Modeling parietal-premotor interactions in primate control of grasping. Neural Networks, 11,1277-1303.

Franz, V. H., Bülthoff, H. H., & Fahle, M. (2003). Grasp effect of the Ebbinghause illusion: obstacle avoidance is not the explanation. Experimental Brain Research, 149,470-477.

Gentilucci, M. (2002). Object motor representation and reaching-grasping control. Neuropsychologia, 40,1139-1153.

Goodale, M. A., & Milner, A. D. (1992). Separate visual pathways for perception and action. Trends in Neuroscience, 15,20-25.

Goodale, M. A., & Westwood, D. A., (2004). An evolving view of duplex vision: separate but interacting cortical pathways for perception and action, Current Opinion in Neurobiology, 14,203-211.

Grèzes, J., & Decety, J. (2002). Does visual perception of object afford action? Evidence from a neuroimaging study. Neuropsychologia, 40,212-222.

Grill-Spector, K. (2003). The neural basis of object perception. Current Opinion in Neurobiology, 13,159-166.

Haart, E. G. O. –de, Carey, D. P., & Milne A. B. (1999). More thoughts on perceiving and grasping the Müller-Lyer illusion. Neuropsychologia, 37,1437-1444.

Haxby, J. V., Horowitz, B., Ungerleider, L. G., Maisog, J. M., Pietrini,, P., & Grady, C. L. (1994). The functional organization of human extrastriate cortex: A PET-rCBF study of selective attention to faces and locations. Journal of Neuroscience, 14,6336-6353.

Hibi, Y., & Yokosawa, K. (2007). On the relation between objects and action: Response consistency and stimulus-response compatibility. Visual Cognition, 15,349-380.

Hughes, L. E., Bates, T. C., & Davies, A. M. (2005). The effects of local and global processing demands on perception and action. Brain and Cognition, 59,71-81.

Kimchi, R. (1992). Primacy of wholistic processing and global/local paradigm: A critical review. Psychological Bulletin, 122,24-38.

Koshino, H., Carpenter, P. A., Keller, T. A., & Just, M. A. (2005). Interactions between the dorsal and the ventral pathways in mental rotation: an fMRI study. Cognitive, Affective, & Behavioral Neuroscience, 5,54-66.

Króliczak, G., Heard, P., Goodale, M. A., & Gregory, R. L. (2006). Dissociation of perception and action unmasked by the hollow-face illusion. Brain Research, 1080,9-16.

Mather, G. (2009). Foundations of sensation and perception. (2nd ed.) Hove: Psychology Press.

Michaels, C. F. (2003). Affordances: four points of debate. Ecological Psychology, 15,135-148.

Miller, J. Navon, D. (2002). Global precedence and response activation: Evidence from LRPs. The Quarterly Journal of Experimental Psychology, 55A,289-310.

Milner, A. D., & Goodale, M. A., (1995). Visual brain in action. Oxford: Oxford University Press.

Milner, A. D., Goodale, M. A. (2008). Two Visual systems re-viewed. Neuropsychologia, 46, 774-785.

Navon, D. (1977). Forest before trees: The precedence of global features in visual perception. Cognitive Psychology, 9,353-383.

Navon, D. (2003). What does a compound letter tell the psychologist's mind? Acta Psychologica, 114,273-309.

Norman, J. (2002). Two visual systems and two theories of perception: an attempt to reconcile the constructivist and ecological approaches. Behavioral and Brain Studies, 25, 73-144.

Paquet, L., & Merikle, P. M. (1988). Global Precedence in attended and nonattended objects. Journal of Experimental Psychology: Human Perception and Performance, 14,89-100.

Pavese, A., & Buxbaum, L. J. (2002). Action matters: The role of action plans and object affordances in selection for action. Visual cognition, 9,559-590.

Pisella, L. Binkofski, F., Lasek, K., Toni, I., & Rossetti, Y. (2006). No double-dissociation between optic ataxia and visual agnosia: Multiple sub-streams for multiple visuo-manual integrations. Neuropsychologia, 44,2734-2748.

Rizzolatti, G., Fogassi, L., & Gallese, V. (1997). Pareital cortex: from sight to action. Current Opinion in Neurobiology, 7,562-567.

Schmuelof, L., & Zohary, E. (2005). Dissociation between ventral and dorsal fMRI activation during object and action recognition. Neuron, 47,457-470.

Symes, E., Ellis, R., & Tucker, M., (2007). Visual object affordances: Object orientation. Acta Psychologica, 124,238-255.

Tipper, S. P., Howar, L. A., & Jackson, S. R. (1997). Selective reaching to grasp: evidence for distractor interference. Visual Cognition, 4,1-38.

Tucker, M., & Ellis, R. (1998). On the relations between seen objects and components of potential actions. Journal of Experimental Psychology: Human Perception and Performance, 24,830-846.

Vainio, L., Ellis, R., Tucker, M., & Symes, E. (2007). Local and global affordances and manual planning. Experimental Brain Research, 179,583-594.

Valyear, K. F., Culham, J. C., Sharif,N., Westwood, D., & Goodale, M. A. (2006). A double dissociation between sensitivity to changes in object identity and object orientation in the ventral and dorsal visual streams: a human fMRI study. NeuroPsychologia, 44,218-228.

Vishton, P. M., Rea, J. G., Cutting, J. E., & Nunez, L. N. (1999). Comparing effects of the horizontal-vertical illusion on grip scaling and judgment: relative versus absolute, not perception versus action. Journal of Experimental Psychology: Human Perception and Performance, 25,1659-1672.

Wilson, H., & Wilkinson, F. (1998). Detection of global structure in Glass patterns: Implications for form vision. Vision Research, 38,2933-2947.

APPENDIX

List of stimuli types used in Experiments 1 and 2.

Stimulus No	Global object position	Global object handle orientation	Local objects position	Local objects handle orientation	Congruence of objects positions between levels	Congruence of objects handle orientations between levels
1	normal	right	normal	right	yes	yes
2	normal	right	normal	left	yes	no
3	normal	left	normal	left	yes	yes
4	normal	left	normal	right	yes	no
5	normal	right	inverted	right	no	yes
6	normal	right	inverted	left	no	no
7	normal	left	inverted	left	no	yes
8	normal	left	inverted	right	no	no
9	inverted	right	inverted	right	yes	yes
10	inverted	right	inverted	left	yes	no
11	inverted	left	inverted	left	yes	yes
12	inverted	left	inverted	right	yes	no
13	inverted	right	normal	right	no	yes
14	inverted	right	normal	left	no	no
15	inverted	left	normal	left	no	yes
16	inverted	left	normal	right	no	no