Research article
UDC 159.9.072
https://doi.org/10.21702/qfdrp682

Perceptual Set Effect in Preschool and Early School-Aged Children Shaped by the Ponzo and Müller-Lyer Illusions

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Abstract

Introduction. A perceptual set is a specific psychological mechanism that shapes the perception of objects based on prior experience, current goals, and the conditions of perception. Previous studies have shown that both realistically different and illusorily distorted objects can create a perceptual set effect in adults. The aim of this study is to experimentally verify the formation of the perceptual set effect in children using the Müller-Lyer and Ponzo illusions, in comparison with the presentation of segments that differ in length. **Methods.** The sample consisted of 26 children with an average age of 6.45 years. The stimulus material was presented in three series: real-different segments (with actual size differences), the Ponzo illusion, and the Müller-Lyer illusion. Each series included 10 setup stimuli and 5 pairs of equal segments to assess the perceptual set effect. Prior to the main experiment, all children underwent diagnostics of visual perception maturity and were divided into two groups based on their level of visual perception constancy maturity. **Results.** Statistical analysis of the experimentally obtained data revealed a perceptual set effect in children with a high level of visual perception constancy maturity, observed in both the series with real-different segments and the Müller-Lyer illusion. Children with low constancy maturity did not exhibit a perceptual set effect. The Ponzo illusion did not produce a perceptual set effect in either group of children. **Discussion.** The results obtained should be regarded as new evidence supporting the idea that the Ponzo and Müller-Lyer illusions belong to distinct categories of illusions.

Keywords

perceptual set effect, Müller-Lyer illusion, Ponzo illusion, visual perception constancy, size estimation

Funding

The study was carried out with the support of the RSF Russian Science Foundation (project No 22-18-00074 – «Psychological mechanisms of coordination of perception and action in illusory context»).

For citation

Romanova-Afrikantova, N. I., Karpinskaia, V. Yu., & Lyakhovetskii, V. A. (2024). Perceptual Set Effect in Preschool and Early School-Aged Children Shaped by the Ponzo and Müller-Lyer Illusions. *Russian Psychological Journal, 21*(4), 22–33. https://doi.org/10.21702/qfdrp682

Introduction

The Perceptual Set Effect is commonly defined as the tendency of an individual to perceive and respond in a certain way (Uznadze, 2001; Uznadze, 1958; Bruner, 1957; Luchins & Luchins, 1970). The term "perceptual set" has evolved to encompass a variety of meanings. One approach to studying perceptual set focuses on its connections with activities, actions, and operations, and also allows for the differentiation of various types of sets, such as target set, operational set, and others (Asmolov, 1979; Arbekova & Gusev, 2017). The perceptual set effect refers to the inaccurate perception of physical properties of objects (such as size, length, weight, brightness, etc.) influenced by the subject's prior experience. In experiments, such prior experience is often induced by presenting a series of stimuli with a fixed physical parameter (for example, a large object on the right and a small one on the left, or a light object in the right hand and a heavy one in the left hand). In the critical trial, two equal objects are presented, and the assimilation or contrast effect is observed in the subjects. The prevalence of these effects depends on both the stimulus parameters and the subject (McKenna, 1984). However, the perceptual set effect does not always occur; in some cases, the set does not appear at all (Uznadze, 1961). The concept of perceptual set is described in various ways, but all approaches share the common idea of perceptual set as the result of cognitive activity (rather than merely receptor adaptation), involving operations such as comparison, generalization, and memorization of stimuli (Baindurashvili, 1986; Deco & Schürmann, 2000; Kostandov et al., 2009; Imedadze, 2023).

Perceptual similarity enhances the size contrast effect, as demonstrated by N. Bruno (2008) in his study of the Müller-Lyer illusion. Bruno proposed that perceptual set distortion is not only due to the characteristics of the visual system, as some researchers have suggested (Jahoda, 1971; Shoshina et al., 2010), but is also influenced by learning and attention processes (Bruno et al., 2008). Kappers and Bergmann Tiest (2014) replicated Bruno's findings, showing that variations in the stimulus set reduce the contrast effect. They argued that cognitive processes involving higher cortical areas play a key role in the formation of perceptual set. In the works of V. M. Allakhverdov, the perceptual set is proposed as a regularity in the functioning of consciousness mechanisms, reflecting a tendency to adhere to a chosen hypothesis (Allakhverdov, 2000). The introduction of irrelevant variables (such as the format in which information is presented) is known to diminish the effect of the set, both perceptually and in Luchins' tasks (Tukhtieva, 2011; Tukhtieva, 2014). The author attributes this result in Luchins' tasks to an increase in conscious control when parameters unrelated to the task are altered – such as changing colors and adding letters and numbers to circles of varying sizes in a series, where the primary distinction among the circles lies in their size.

A perceptual set can be formed not only through the use of genuinely different objects but also via illusions or by imagining such objects (Kostandov et al., 1998; Valerjev & Gulan, 2013; Karpinskaia et al., 2018; Grigolava, 1987). This suggests that what matters more in creating a set effect is not the actual physical difference between stimuli, but rather the subjective perception of that difference. Despite this, few experiments have specifically explored the perceptual set effect based on illusions. It is well-established that different types of illusions are likely associated with various psychophysiological mechanisms (Coren et al., 1976; Menshikova, 2012; Menshikova, 2013; Karpinskaya & Lyakhovetskii, 2014; Karpinskaia et al., 2023). The strength of the illusory effect can vary depending on the presentation context or the individual characteristics of the subject.

The strength of the illusory effect and the persistence of the perceptual set effect vary across age groups. Preschool and early school-aged children, like adults, are susceptible to the effects of set (Romanova-Afrikantova et al., 2023; Leibowitz & Judisch, 1967; Brislin, 1974). However, conducting experiments with preschool children can be challenging due to the need for a clear understanding of instructions and the ability to provide coherent responses. Few studies have investigated cognitive illusions and the perceptual set effect in children, and those that do typically focus on children as young as 5 or 6 years old. At this age, key mechanisms of visual perception, such as perceptual (subjective) constancy, are likely to be developing, which may contribute to changes in the strength of visual illusions (Rozhkova et al., 2005; Ognivov, 2008; Romanova-Afrikantova et al., 2023). The perceptual set effect is also linked to mechanisms of perceptual constancy (Kezeli et al., 2021). It has been shown that the perceptual set effect is less pronounced in children aged 7–10 years compared to those aged 11–18 years and 19–68 years (Cunningham, 1965; Pope et al., 2015). Similarly, the strength of geometric illusions changes with age (Leibowitz & Judisch, 1967; Brislin, 1974; Rival et al., 2003). In our previous study, we

examined the strength of the Ponzo illusion in preschool and early school-aged children and found that the magnitude of the illusory distortion was related to both age and the development of perceptual constancy (Romanova-Afrikantova et al., 2023). Given that the strength of the Ponzo and Müller-Lyer illusions varies with different levels of perceptual constancy maturity, we hypothesized that these differences would also be evident in the formation of the perceptual set effect.

Aim of the study

The aim of this study is to investigate the perceptual set effect on both real and illusory stimuli (specifically, the Ponzo and Müller-Lyer illusions) in preschool and early school-aged children.

Methods

Participants

The study included 26 children (15 girls and 10 boys) aged 5 years and 6 months to 8 years and 6 months, with an average age of 6.45 years. All participants were typically developing, and all were right-handed.

Stimulus material

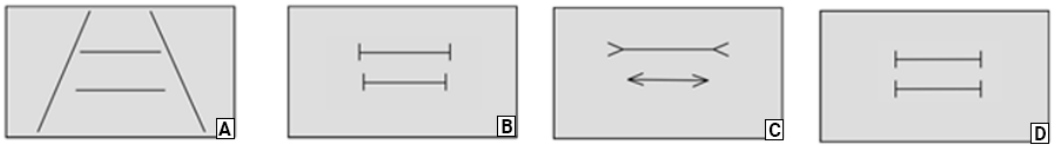
На этапе формирования установочного эффекта использовались три вида стимулов:

1. The Müller-Lyer illusion: two identical horizontal segments are positioned one above the other. The upper segment is flanked by arrows pointing outward, while the lower segment is flanked by arrows pointing inward toward the segment's endpoints (Fig. 1C).
2. The Ponzo illusion: two identical horizontal segments are positioned one above the other between two vertical lines that converge toward the top of the screen (Fig. 1A).
3. A pair of segments bounded by vertical serifs, differing in actual size: the upper segment is 5–30 mm longer than the lower one (Fig. 1B).

During the stage of assessing the strength of set distortion, control stimuli that did not induce any illusory distortion were used: two equal horizontal segments positioned one above the other and bounded by vertical serifs (Fig. 1D).

All stimulus types featured a pair of central horizontal segments. The segments were black and displayed on a white screen, with lengths ranging from 50 to 500 mm, and all lines had a thickness of 1 mm.

Figure 1
Stimulus Material



Note. *A –Ponzo illusion, B – segments with actual size differences, C – Müller-Lyer illusion, D – control stimuli with equal size differences.*

Research procedure

Before taking part in the main experiment, participants were assessed for their level of visual perception development.

For the assessment, we used the 'Methodology for Assessing the Level of Visual Perception Development in Children Aged 5 to 7.5 Years,' a revised and comprehensive test developed by M. Frostig (Bezrukikh, & Morozova, 1996). We used Subtest 3, 'Constancy of Contours,' which is designed to assess the perceptual constancy (Morozova, 2008). Subtest 3 involves recognizing a central geometric figure presented in varying sizes, tones, textures, and spatial positions. A circle and a square are used as the central figures to be identified.

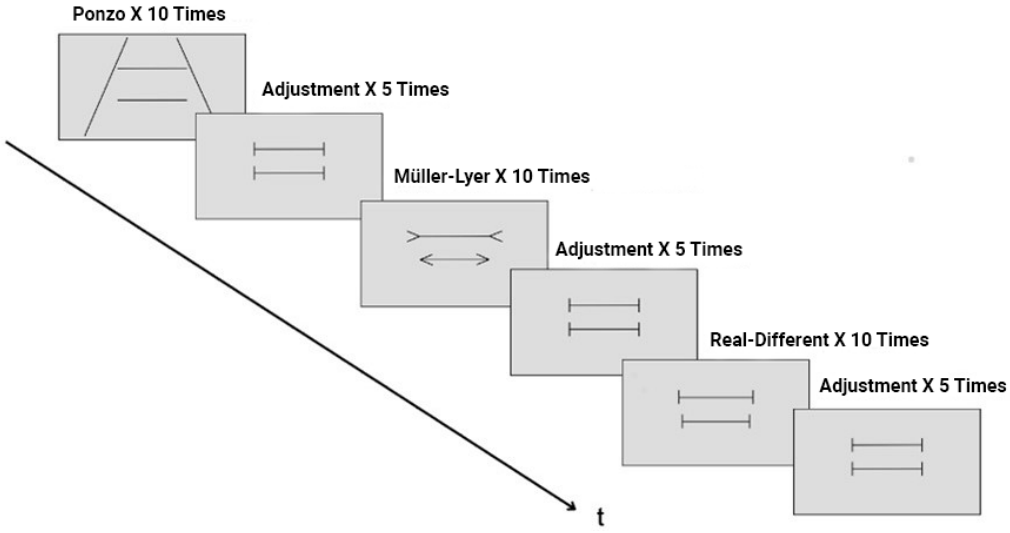
Based on the results of the perceptual constancy assessment, the subjects were divided into two groups: the group with a conditionally low level of constancy maturity (group of children with lower maturity), consisting of children who scored 10 points or fewer, and the group with a conditionally high level of constancy maturity (group of children with higher maturity), consisting of children who scored more than 10 points.

The original software developed by the authors was used in the experiment. Each participant was presented with three series of stimuli on the monitor of an HP Envy 17-n153nr laptop (Figure 2).

Each series consisted of 10 setup stimuli (Fig. 1A, B, or C) and five pairs of equally sized segments (Fig. 1D) to assess the perceptual set effect. The order of presentation of the series for each participant was determined randomly, with a 1-minute pause between series.

During the formation phase of the perceptual set effect, participants were asked to view stimuli presented sequentially on the screen. The presentation time for each setting stimulus was 1 second, with a 1-second pause between presentations. The total duration of the experiment was approximately 7 minutes per participant (excluding the time for level of visual perception development assessment).

Figure 2
Example of Stimulus Presentation Order to the Subjects



For the verbal assessment of control stimuli with equal size differences, the method of adjustment was used: the participant was asked to make the segments equal by giving verbal instructions to the experimenter to decrease or increase the length of the lower segment. As soon as the participant believed the segments were equal, they would say 'stop,' and the next pair of stimuli would appear on the screen. The length difference between the segments was fixed. The strength of the perceptual set effect was calculated as the difference in length between the lower and upper segments, expressed as a proportion of the upper segment's length. "Negative values of the set effect strength indicate an assimilation set effect (where the length of the upper segment of the neutral stimulus is greater than that of the lower segment, as in the stimuli from the formation phase), while positive values indicate a contrast set effect.

The statistical significance of the set effect was assessed at the $p < 0.05$ level using the Wilcoxon test. Data processing was conducted using Prism 10 for macOS (Version 10.1.1, 270) (GraphPad Software, La Jolla, CA, USA). The data are presented as mean $\pm$ standard deviation.

Results

The group with a conditionally high level of constancy maturity included 17 children, while the group with a conditionally low level of constancy maturity consisted of 9 children.

Figure 3 illustrates the strength of the perceptual set effect as a function of the type of setting stimuli and the subjects' level of perceptual constancy maturity. Although subjects

were presented with equal segments during the test phase, under the influence of the perceptual set effect, they tended to adjust the length of the lower segment, making it shorter than the upper segment.

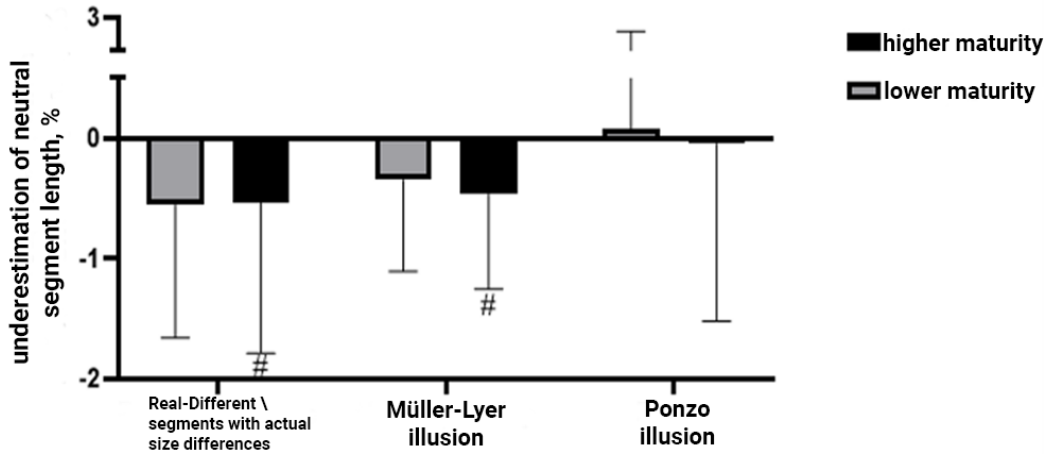
The stimulus series using segments with actual size differences demonstrated a perceptual set effect (-0.54 ± 1.21%, W (26) = -2, p = 0.0215). When the children were divided into two groups based on their visual constancy maturity, the group of children with higher maturity exhibited a set effect (-0.54 ± 1.25%, W (18) = -39, p = 0.0488), whereas the group of children with lower maturity showed no set effect (-0.55 ± 1.10%, W (9) = -13, p > 0.05).

The series of stimuli creating the Müller-Lyer illusion also resulted in perceptual set formation (-0.43 ± 0.78%, W (26) = -75, p = 0.0061). Similar to the case with the segments with actual size differences, the group of children with higher maturity in perceptual constancy exhibited a set effect (-0.46 ± 0.79%, W (18) = -32, p = 0.0234), whereas the group of children with lower perceptual constancy maturity showed no set effect (-0.35 ± 0.76%, W (9) = -13, p> 0.05).

The Ponzo illusion did not produce a significant set effect in the subjects (-0.003 ± 1.59%, W (26) = -2, p> 0.05). Additionally, no attitudinal effect was observed in either of the groups with different levels of visual constancy maturity: (-0.045 ± 1.47%, W (17) = 0, p> 0.05 for the group with high constancy maturity and -0.007 ± 1.89%, W (9) = -1, p> 0.05 for the group with low maturity).

Figure 3

Perceptual Set Effect Strength Based on Stimulus Type and Subjects' Perceptual Constancy Maturity



Note. *# – p <0.05. Mean ± Standard Deviation.*

Discussion

We obtained data that confirm earlier findings on Uznadze's classical set formation in preschool and early school-aged children, where stimulus segments with actual size differences are used to create a perceptual set effect. Consistent with previous studies, we observed a persistent perceptual set effect (Ashkinazi, 2007; Kostandov et al., 2005; Kostandov et al., 2008).

A perceptual set effect was formed in children based on the Müller-Lyer illusion, whereas no perceptual set effect was observed based on the Ponzo illusion. Given that Müller-Lyer and Ponzo illusions may involve different mechanisms of formation and manifest differently depending on age (Karpinskaya & Lyakhovetsky, 2014; Coren et al., 1976; Rozhkova et al., 2005), we can hypothesize a connection between the absence of a perceptual set effect and the mechanisms underlying illusory perception formation. However, further verification is needed. Pollack (1964) demonstrated that the strength of the Müller-Lyer illusion was influenced by how it was presented. In the classical presentation method (where the illusion and full image are shown at once), children were susceptible to the illusory effect. However, when a tachistoscope was used to sequentially present separate segments and arrows that created the Müller-Lyer illusion, the illusory effect was found to depend on prior experience and the development of cognitive functions (Pollack, 1964). Our findings align with Pollack's results: children with higher visual constancy maturity, in contrast to those with lower maturity, are more susceptible to the perceptual set effect induced by the Müller-Lyer illusion.

The lack of a perceptual set effect when using the Ponzo illusion in children may be due to the fact that the mechanisms associated with this illusion have not yet fully developed in children. It is likely that hyperconstancy effects (Romanova-Afrikantova et al., 2023) and the relatively limited influence of prior experience (Reese, 1963) contribute to this absence.

We found no significant difference in the strength of the perceptual set effect caused by the Ponzo illusion between groups of children with varying levels of visual constancy maturity. This can primarily be explained by the fact that, in general, we did not observe a set effect of the Ponzo illusion in children. Future research should explore the hypothesis that the phenomenon of perceptual hyperconstancy, which accounts for greater illusory distortion in older preschool children compared to younger school-aged children (Romanova-Afrikantova et al., 2023; Ognivov, 2008; Shallo & Rock, 1988), may help explain the resistance of children's perception to the formation of a perceptual set using the Ponzo illusion.

Conclusion

We conducted a study on the perceptual set effect using both real-different segments (segments with actual size differences) and illusory stimuli (Ponzo and Müller-Lyer illusions)

in preschool children. Our findings confirmed the possibility of creating a perceptual set effect in children with real-different segments and provided new insights into how the perceptual set effect manifests when physically equal segments are presented in the Müller-Lyer illusion. The investigation into the relationship between the magnitude of the perceptual set effect and the maturity of visual perception constancy revealed that children with a higher level of visual constancy maturity are more susceptible to the perceptual set effect. However, the segments within the Ponzo illusion did not produce a perceptual set effect in preschool children

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Received: 25.02.2024
Revised: 24.07.2024
Accepted: 26.08.2024

Author Contributions

Nataliia I. Romanova-Afrikantova conducted the experiment, statistical analysis, and prepared the text of the article.

Valeriia Yu. Karpinskaia designed the study and prepared the text of the article.

Vsevolod A. Lyakhovetskii designed the study, conducted statistical analysis, and prepared the text of the article.

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Conflict of Interest Information

The authors have no conflicts of interest to declare.