Global and local perceptual processes in 3 ½ year old children

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Abstract

This study observes global and local processing in 3 ½ year old children to understand developmental trajectories at this age, and explores correlations of global and local processing to ASD risk. Participants were selected at 12 months old based on their successful completion of the FYI (First Year Inventory), a parent questionnaire that assesses early risk for ASD. Twenty-nine typically-developing 3 ½ year olds performed a forced choice Navon shape task, in which they were presented with shapes that contained both local and global levels, and then two shapes at either the local or global level. They were instructed to choose which one they saw first. Higher global scores were slightly correlated to higher risk scores from the FYI. These results are discussed in the context of global and local processing in ASD groups and typically-developing groups.

Global and local perceptual processes in 3 ½ year old children

An important early process of visual cognition is the organization of visual input, which allows us to make sense of objects and scenes in our environment in predictable ways. When we perceive an image locally, we parse it into separate units. These local features consist of all the component parts of an object; for example, when viewing a house we may see the shutters, the door, or the windows. The ability to notice the local features of an object or situation may enable us to remember a single item on a grocery list, or to locate an individual in a crowd. When we perceive an image globally, we see the whole or the gist of its parts: we see the house in its entirety. Global processing allows us to combine the objects of our surroundings into scenes, creating meaning and context. Meaningful interaction with the world requires successful utilization of both local and global perceptual processes.

To understand the way that adults process local and global information, David Navon (1977, 1981) created hierarchically structured patterns or figures containing a large global level and smaller local level. Consider the example of a rectangle made up of smaller triangles. The overall contour and shape of the rectangle is considered the global aspect of the figure, and the smaller triangles are considered the local aspects of the figure. In a Stroop-like interference task, (Navon, 1977, Experiment 3) subjects were presented with large characters made out of small ones and told to recognize either just the large characters or just the small ones. Whereas the identity of the small characters had no effect on recognition of the large ones, large character global cues conflicted with the small character local cues and inhibited the participants' responses to the local level. This experiment suggests dominance of global structure in visual perception, or a global precedence effect in adults, where the global properties of a visual object are processed first, followed by analysis of local properties. More recent research on adults has replicated these results (see Kimchi, 1992 for a review).

It is clear that adults tend to perceive stimuli more globally, but in infants, it is still unclear whether they perceive things more globally or locally, or when global and local perceptual processes develop. Research suggests that infants can perceive local and global changes in their environment. Cassia, Simion, Milani, and Umitla (2002) found that newborn infants look longer at changes in both local features and global features, and Ghim and Eimas (1988) found similar results in 3-month-olds. Some research suggests that newborns have an initial global bias, as they appear to fixate on external contours, attention to interior details coming at 3 months old (Fantz, 1961; Ghim & Eimas, 1988; Quinn & Eimas, 1986). Additional research indicates that newborns have a global bias that persists to 12 months (Macchi Cassia, Simion, Milani, & Umiltà, 2002), while contrasting research suggests that infants have a local bias that persists into early childhood (Porporino, Shore, Iarocci, & Burack, 2004; Scherf, Behrmann, Kimchi, & Luna, 2009).

Research on toddlers and young children suggest that they are able to attend to both the local and global elements of spatial patterns. Under appropriate conditions, children in the early preschool period can perceive and name both global and local attributes (Prather & Bacon, 1986) and children as young as 3 can separate simple geometric forms into well-defined parts and use these elements to form a coherent whole (Stiles, Delis, & Tada, 1991). There is, however, a lack of research on the nature and developmental trajectory of global and local perceptual processes in this age group. In one experiment, 3-5 year olds were asked to describe simple part/whole pictures. When compared to the 4 and 5 year olds, the 3 year olds described only the local aspects of the pictures, indicating a piecemeal local processing approach. Importantly, the experimenters used a paradigm that relied on verbal encoding, so it is not clear if these responses reflect real developmental differences in perception or merely age-related language deficits (Prather & Bacon, 1986).

There is more research on children age 4-7, and there is a general consensus that they process visual stimuli differently and perhaps more incompletely than adults. Children's global processing appears to be more vulnerable to changes in task difficulty and stimulus structure, which can be demonstrated when fewer local items are used to form the global level of the stimulus (Dukette & Stiles, 2001). In a study by Dukette and Stiles (1996), experimenters asked 4 year olds, 6 year olds, and adults to choose which of two geometrical figures was most like a target hierarchical pattern. Patterns closely approximated those used in adult studies in size and density of the local elements, and all age groups exhibited a bias to choose figures made of shapes that reflected the global level of the target figure. Patterns were then manipulated to have fewer local items making up the global level. With decreased density of local elements, the 6-year olds and adults continued to display a global bias, while the 4-year olds chose patterns corresponding to the local level elements. This finding suggests that children have a local bias that continues to undergo developmental change during the preschool period. Specifically, the child's ability to integrate spatially separate parts into a meaningful whole improves.

This local bias changes throughout development to reflect a more adult global precedence later, but it is unclear at what age children's processing completely reflects adult perception. One study examined the processing of local and global perception in relation to selective attention. With the presence of neutral distractors, children age 6 to 8 had the greatest increase in reaction time for global targets relative to local targets, indicating less developed global processing. There was no effect from distractors on the global processing of 10-year-olds, 12-year-olds, and adults, suggesting that the age range in which children begin to reflect adult global processing is between 8 and 10 years of age (Porporino et al., 2004). Some research suggests that global processing continues to improve after 8 years of age (Burack, Enns, Iarocci, & Randolph, 2000; Vinter, Puspitawati, & Witt, 2010) and other research has proposed that a global precedence may continue to develop late into adolescence (Scherf, Behrmann, Luna, & Kimchi, 2009).

There have been interesting dissociations observed between global and local processing in atypically-developing populations. Individuals with Down syndrome tend to favor global processing at the expense of local processing (Porter & Coltheart, 2006). Alternatively, individuals with Williams Syndrome or autism spectrum disorder (ASD) tend to favor local over global processing (Porter & Coltheart, 2006). Individuals with schizophrenia seem to exhibit deficits in processing local information (Bellgrove, Vance, & Bradshaw, 2003) and individuals with obsessive-compulsive disorder may process local information at the expense of global information (Yovel, Revelle, & Mineka, 2005).

Research on global and local perception in individuals diagnosed with ASD has garnered an especially high level of interest with a number of studies looking at patterns of local and global processing (for example: Rinehart, Bradshaw, Moss, Brereton, & Tonge, 2000). An early cognitive theory in the ASD literature in global and local processing was the central coherence theory proposed by Uta Frith in 1989. Central coherence is the tendency for typically-developing children and adults tend to draw together diverse information to construct higher meaning, favoring the gist over the specific details. Individuals with ASD have weak central coherence, as they tend to process the local details of information over the global gist of the information (Frith, 1989). This theory was based on superior scores from ASD groups on the EFT (Embedded Figures Task), in which participants need to find that hidden shape embedded in a large complex design, as well as findings from the Block Design Task (Kohs, 1923) which involves breaking up line drawings into units, so that individual blocks can be used to reconstruct the original design from separate parts (Frith & Happé, 1994). Both of these tasks indicate higher processing of local information in ASD groups.

Since the proposition of the central coherence theory, research has indicated that individuals with ASD have preserved global processing, but that they exhibit superior local processing (Jolliffe & Baron-Cohen, 2001; Plaisted, Saksida, Alcántara, & Weisblatt, 2003). This led to the idea of weak central coherence in ASD populations to be redefined as a superior local processing ability without a necessary deficit in global processing (Happe & Frith, 2006).

Although these theoretical ideas remain at the forefront of ASD research, results from studies observing global and local perception in both children and adults with ASD have been mixed. A number of studies have found superior local processing in ASD groups compared to typically-developing groups (Wang et al., 2007; Behrmann et al., 2006; Rinehart et al., 2000) and other studies have found comparable performance on local and global processing between ASD groups and typical controls (Hayward et al., 2012; Ozonoff, Strayer, McMahon, & Filloux, 1994; Plaisted et al., 1999; Scherf et al., 2009).

Inconsistencies in the methods and task structure may account for these discrepancies in the research literature. In one study, children with ASD performed similarly to typically developing children in a "selective attention task", in which they were told to globally attend to one block of trials, and locally in another block. However, in a "divided" attention task with the same stimuli, in which participants were told to attend to both global and local levels, children with ASD performed better with local targets while typically-developing children performed better on the global targets (Plaisted et al., 1999). Another study found that when children with

ASD were given the choice to report global or local information, they were less likely to report information on the global level, but when they were specifically instructed to report global information, they performed similarly to typical children (Koldewyn, Jiang, Weigelt, & Kanwisher, 2013).

Mixed results could also be explained by differences in the target populations. Baron-Cohen and colleagues (2001) suggest that there are varying degrees of cognitive deficits observed in individuals with ASD, and that a range of autistic traits lies on a continuum (Baron-Cohen, Wheelwright, Skinner, Martin, & Clubley, 2001). In one study, autistic individuals and individuals with Asbergers were observed in a global/local task. Errors made by the autistic individuals on a global task differed significantly with the control group, while errors committed by the Asbergers group were comparable to their matched control group (Rinehart et al., 2000). It is important to note, however, that the DSM-V no longer recognizes Asbergers as its own disorder and results may or may not reflect perceptions of kids with diagnoses.

Although individuals with ASD are predicted to be at the extreme weak end of coherence, exhibiting a local bias, Happé and Frith (1994) suggest that weak and strong coherence lie on a continuum, reflecting individual variation among typically-developing individuals. This variation has been observed in typically-developing populations on their performance on the EFT. Individuals who are slower at locating the hidden figure are characterized to have a global information processing approach, unlikely to automatically break the task down into parts. In contrast, other individuals characterized by having a more locally oriented information processing approach found the hidden shape more quickly, suggesting that they were less distracted by the prevailing context and more able to focus on the constituent parts of the stimulus (Witkin, Goodenough, & Karp, 1967).

Thinking about weak coherence as one end of a normal continuum in cognitive style suggests that this may be one aspect of the broader autism phenotype. The Autism-Spectrum Quotient (AQ) was developed to identify the extent of autistic traits shown by an individual of normal intelligence. Using the AQ, social and non-social characteristics of individuals can be quantitatively measured (Baron-Cohen et al., 2001). A recent study analyzed scores of typically-developing adults on the AQ and found that, relative to low scorers, those who scored higher on autistic-like traits were quicker at finding the local target on the EFT, suggesting they had a locally oriented processing approach (Almeida, Dickinson, Maybery, Badcock, & Badcock, 2012).

In both atypically and typically developing populations, research has focused on adults and older children, with little understanding on how preschool aged children perceive information. More research is needed to understand the developmental processes underlying global and local perception. There is also a need for further research on perceptual processing across the range of typical and atypical development, to increase our understanding of how hierarchical processing develops and whether or not it is related to ASD risk or symptomatology. The current study is designed to assess local and global processing in 3 ½ year olds in relation to risk for ASD. The measure of risk used in this study is the The FYI (First Year Inventory), a 63-item parent report screening tool designed to identify 12-month-old infants who are at risk for an eventual diagnosis of ASD (Reznick et al., 2007).

Methods

Participants

Participants included children who were recruited within 3 weeks of the date they turned 42 months (3 ½ years old). The sample came from a larger group who had previously completed the First Year Inventory (FYI), a questionnaire that was sent in the mail and completed by the parent when children were 12 months of age, as a part of the Early Development Project (EDP) in UNC-Chapel Hill's Department of Allied Health (Reznick et al., 2007). Those who had expressed interest in being contacted for follow up studies were recruited by phone call, and asked to complete an online survey. In addition, parents who lived within a 25-mile radius of the lab were invited to participate in the lab component. A total of 108 children participated in lab tasks (Table 1) and the present study includes 32 participants. However, children who did not understand the task (*n*=3) were excluded in further analyses. The majority was female (20 female and 9 male). A large percentage of the children (92.8%) were identified as Caucasian, and 96.3% of the mothers indicated that they had at least a college degree. A household income of 90,000-250,000 (*n*=21, 72%) was most common in this sample. Demographics from this subset can be found in Table 2. In the picture task, children who did not respond to the experimenter (*n*=5) were excluded from further analyses.

Measures

The forced choice global task included simple hierarchical shapes influenced by those used by Navon (1977). Six shapes were used containing both local and global elements familiar to 3½ –year-olds: rectangle, square, triangle, rhombus, diamond, and circle. The experimenter sat across from the child, and said, "I am going to show you some pictures and ask you some questions." The experimenter first presented a flashcard with the hierarchical shape, which included a global, bigger shape made up of smaller, different local shape elements. After 2 seconds, the experimenter presented to the child an 8x10 piece of paper with the local aspect of the shape on one side, and the global aspect of the shape on another, counterbalanced. The experimenter then asked the child, "Which *one* did you see? Point to which one you saw" emphasizing that the child needed to choose one. The shape that the child pointed to was coded as either global or local.

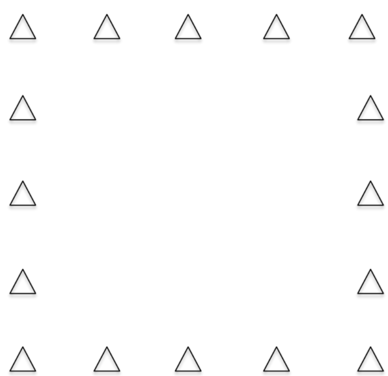

Figure 1. An example of the target hierarchical shape used in the local/global shape task.

The next task included pictures of faces made out of vegetables by Giuseppe Arcimboldo, a 16th century painter, based on the idea that if individuals with autism are less sensitive to the global whole of objects, they may also be less inclined to perceive faces as organized and meaningful wholes (Gross, 2005). The child was told that he/she would be shown some different pictures, and was instructed to tell the experimenter what he/she saw. Then, the experimenter presented a picture for 3 seconds, and asked, “What do you see?” After 3 seconds, the experimenter put the picture away from the view of the child. Verbal responses were coded to be local if they included elemental aspects of the picture, such as “vegetable”, “fruit” and “apple”, while responses such as “face” and “man” were coded to be global.

Figure 2. The Vegetable Gardner: example of stimuli for picture task. (Arcimboldo, c. 1590).

Procedure

The assessment began in a quiet room, with age-appropriate toys laid out on the floor. To get acquainted with the space, children and their parents played together for 8 minutes before doing the task. The forced choice global/local task and the picture task were the first tasks the child completed in a series of executive function tasks. One to two people operated a camera, which fixated on the test stimuli, and one experimenter ran the tasks with the child. The parent sat in a chair near the child for the task, filling out a survey. Parents were instructed not to provide any feedback or prompt the children on any tasks.

Results

To assess the relationship between amount of risk indicated from the child's FYI score and their overall global score, data were analyzed using Pearson correlations. Scores ranged from 0 (more local) to 1 (more global) and for the local/global shape task, each child received a total score (*M*=0.66, *SD*=.25). There was a non-significant but trending positive correlation between the risk percentile and total score, $r(29)=0.30$, $p=.11$. A scatterplot summarizes the relationship between risk percentile and total score (Figure 3). Sensory regulatory risk was also calculated (Figure 4) and there was a positive correlation, $r(29)=.37$, $p=.04$ but there was a floor effect such that more than 50% of the sample had sensory regulatory scores of 0.

Participants performed significantly differently on the picture task and the shape task, $t(26) = 11.57$, $p < .0001$. On the local/global shape task, the children on average pointed more often to the global level shape ($M=0.66$, $SD=.25$), whereas on the picture task, participants much more likely to respond by naming local parts of the picture ($M=0.03$, $SD=.11$).

Discussion

The present study used a global/local shape task and a picture task to examine perception of hierarchical stimuli in typically-developing 3 ½ year olds and global and local perception in relation to early ASD risk. First, it was expected that children who perceived stimuli more locally would have higher ASD risk scores. This was based on much of the ASD research, which has generally observed enhanced local processing, as well as Frith and Happé's theory (1994) that suggests that coherence is on a continuum, and individual differences are present in the typically-developing population. The results of this study went against the original hypothesis that higher local perception would be correlated with higher risk. In fact, higher global scores were slightly correlated with higher risk of ASD. In general, children were more global in their perception in the global/local shape task, but significantly more local in the picture task.

There are a few reasons why global scores could have correlated to higher risk for ASD. First, in the study of local and global perceptual processing, the research in ASD populations has been mixed; studies have found comparative local processing to typically-developing populations (Hayward et al., 2012; Ozonoff, Strayer, McMahon, & Filloux, 1994; Plaisted et al., 1999; Scherf et al., 2009) and one study even found enhanced global processing in adolescents and adults with ASD (Perreault et al., 2011). Therefore, it is difficult to generalize the way that children with ASD perceive global and local information.

Second, the present sample only included infants who were not labeled “at risk” for an eventual diagnosis of ASD, based on social-communication and sensory-regulatory domains of risk on the FYI. Many children had risk scores of 0. A more heterogeneous sample, including children with a larger range of risk scores, could have more accurately measured the two variables. Another limitation of this study was the small sample size, with most children (*n*=20) belonging to families that were in a relatively high in socioeconomic status, with a household income of $90,000-250,000.

Differences in the stimuli used in the shape task may have contributed to the participants generally perceiving the shapes globally. For example, stimuli in both tasks were not measured for the amount of space between the elements or relative size of the configuration, which was a limitation in the present study. A study by Kinchla and Wolfe (1979) found that varying the overall size of the hierarchical stimuli affected global/local responses. At the larger sizes, subjects demonstrated a local level response bias, but for the smaller sized forms, subjects were better at global level identifications. Additionally, Dukette and Stiles (1996) observed that hierarchical figures that included elements spaced farther apart led to an underlying bias in children to process stimuli more locally. Many studies observing children have found a local bias, but results appear very sensitive to methodology, and different spacing between elements may lead to different results.

When children in the present study were asked to describe what they saw in the picture task, the overwhelming majority of children named vegetables, fruits, or other component and local features. Given the saliency of faces and face processing in humans, one might expect that the global whole of the face would be very meaningful and quickly perceived before other details. Referring to adults, Navon mentions these specific fruit pictures in his 2003 review, suggesting that if compound stimuli contain objects, the global form is already processed to some extent, and that "it would turn out unlikely that we focus early on some local constituent of any object" (p. 283). Consistent with the idea that adults are globally biased, the local responses on the face pictures could have been due to the age of participants. Based on previous research with this age group (Prather & Bacon, 1986) it is likely that young children have a local bias. The nature of global and local perception is still unclear in children under the age of 4, but given the perceptual saliency of faces, results from this study indicate that there is indeed a strong local bias in 3 ½ year olds. Another possible explanation for the strong local bias is that the face stimuli were too large on the page, which may have led to children focusing on the elements more. The Navon shapes took up less of the page, which could have made the local elements too small and therefore deemphasized in relation to the global element.

Almost all the children perceived the face stimuli locally, so there was no correlation to their perception and their ASD risk scores. As mentioned previously, the size of the stimuli could have led to overall elemental processing, and the use of different hierarchical stimuli could yield more varied responses, which could then be assessed in relation to ASD risk. Many studies have shown that individuals with ASD tend to selectively attend to local elements of stimuli (Plaisted, 1999) so it may be the case that individuals with ASD are less inclined to perceive faces as meaningful wholes. People with autism have been found to focus on specific regions or featural parts of the face for social information (Baron-Cohen, Wheelwright, & Joliffe, 1997) and may have more difficulty recognizing and remembering faces (de Gelder, Vroomen & Van der Heide, 1991). According to Frith's theory of coherence, one could suggest that weakened coherence alone may account for more problematic processing of faces, stemming from the ability to put together features to form a whole face. Or, a local perceptual bias alone may bias a person with ASD to focus too much on the elemental properties of the face, inhibiting a more global response to face processing. Although we cannot generalize these hallmarks of face processing in autism to apply to the present study, coherence in typically-developing children observed in relation to more varied hierarchical face stimuli may reveal underlying differences in the way that they focus on local versus global elements, which may give us insight in their approach to real-life face processing.

The finding that children's observations on the picture task differed so much from the global/local shape task was unexpected, and may support the mixed results in the present research on local and global processing. As it stands, the terms "global" and "local" are very broad and loosely defined. Perhaps this confusion is why studies have not consistently used the same stimuli, in their measurements of the elements and density (Kimchi, 1992). Methods have differed in the research, with some studies asking the child to determine which shape is similar to another, others asking them to selectively attend to local or global blocks (Plaisted et al., 1999), and some studies have asked children to draw figures and have judged them for the local or global features (Vinter et al., 2010). Based on the results from the present study, differences in the nature of the stimuli presented may yield completely different results. Future studies could employ pictures or real-life stimuli that contain global and local elements, and compare these to responses from traditional Navon shapes, to better understand any possible differences in the method used while better defining the nature of local and global perception.

More research needs to be done on typically-developing populations as young as 3 ½ years old. Understanding the way in which these populations perceive stimuli would better inform us of what to expect on global and local tasks at this age, allowing us to better understand the nature of differences between low and high ASD risk groups. Research could also explore development of hierarchical processing as a general cognitive style in diverse populations. This has already been explored on the EFT (Witkin, Goodenough, & Karp, 1967) but more diverse tasks might be necessary to better interpret individual differences in the context of global and local processing.

The present study indicates that 3 ½ year old children see hierarchical stimuli of faces more locally, and see Navon hierarchical shapes more globally. This global bias was correlated with higher ASD risk, which goes against the current research on individuals with ASD. This study adds to the research on 3 ½ year olds and how they perceive hierarchical stimuli in the world. Every day, we used global and local processing to perceive stimuli and to make quick perceptual judgments. Therefore, studying individual differences in the nature of processing in both typical and atypical populations could have implications for a range of things, such as reading ability or later academic success. More work could be done to understand the nature of global and local processing in young children, and the nature of these perceptual differences in various populations.

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Table 1. Participant demographics

	Full 42-month sample, *N* = 108	Local-Global Task sample, *N* = 29
	N (%)	N (%)
Child Gender		
Male	54 (50.0)	9 (31.0)
Female	54 (50.0)	29 (69.0)
Race		
Caucasian	88 (83.8)	26 (92.9)
Other	5 (4.8)	2 (7.2)
Mother Education		
Completed HS	0	1 (3.7)
Some college	5 (4.8)	11 (40.7)
4-year College Grad.	36 (34.6)	11 (40.7)
Post-graduate	63 (60.6)	4 (14.8)
Household income		
Less than $35,000	5 (4.8)	1 (3.6)
$35,000-$60,000	10 (9.5)	4 (13.7)
$60,000-$90,000	17 (16.2)	3 (10.3)
$90,000-$250,000	21 (40.0)	20 (71.4)

Figure 3: Total Global Score Correlated with Risk Percentile

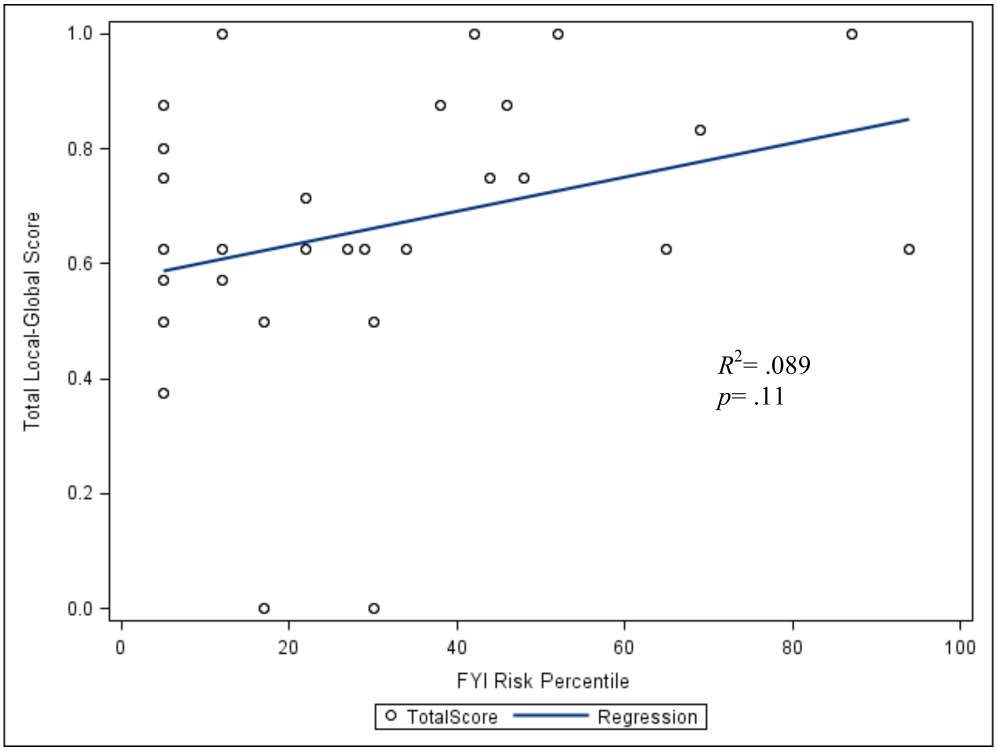

Figure 4: Global Score correlated to Sensory-Regulatory Risk