The context-sensitivity of visual size perception varies across cultures

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First draft submitted 7th November 2007

Revision submitted 4th April 2008

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Abstract. There is evidence that East Asian cultures have more context-sensitive styles of reasoning, memory, attention, and scene perception than western cultures. Lower levels of the perceptual hierarchy seem likely to be similar in all cultures, however, so we compared context-sensitivity in Japan with that in the UK using a rigorous psychophysical measure of the effects of centre-surround contrast on size discrimination. In both cultures context-sensitivity was greater for females working in the social sciences than for males working in the mathematical sciences. More surprisingly, context-sensitivity was also much greater in Japan than in the UK. These findings show that, even at low levels of the visual processing hierarchy, context-sensitivity varies across cultures, and they raise important issues for both vision scientists and cross-cultural psychologists.

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1 Introduction

Context-sensitivity is central to cognition in general, and to perception in particular. Within the visual system much is known about its anatomical and physiological bases (Phillips and Singer 1997), and about its role in psychopathology (Phillips and Silverstein 2003; Uhlhaas and Silverstein 2005). Contextual interactions can be defined as those that affect signal processing without changing what the signals mean (Kay et al 1998). Contextual interactions are neither necessary nor sufficient for signal transmission, but their modulatory effects play a major role in producing a coherent response to the situation as a whole.

Two broad cognitive styles have been distinguished: one that has low context-sensitivity and is therefore local, field-independent, and focussed on detail, and one that has high context-sensitivity and is therefore global, field-dependent, and focussed on gist (e.g. Happé and Frith 2006). Males tend to have low context-sensitivity (Phillips et al 2004), as do people with autistic spectrum disorders ("weak central coherence"; Frith 2003).

Independently of these advances, there has been a growing interest in cross-cultural comparisons between cognitive styles in East Asian and western cultures. Within anthropology the concept of 'high context' and 'low context' societies has arisen to distinguish between highly communal and highly individualistic societies (Hall 1976). Within cross-cultural psychology the distinctions between collectivistic and individualistic cultures, and between 'holistic' and 'analytic' cognitive styles now play a central role (Nisbett et al 2001; Nisbett and Masuda 2003; Heine, 2008). Nisbett and Miyamoto (2005) conclude that people in individualistic western cultures tend to engage in context-independent analytic perceptual processes, whereas people in East

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Asian cultures, such as China, Korea, and Japan, tend to engage in context-dependent holistic perceptual processes.

Most of the evidence for these cultural differences in context-sensitivity comes from studies of high-level processes, such as the attribution of causality, categorization, attention, working memory, and scene perception. Cultural differences now need to be studied using the rigorous psychophysical methodologies that have recently been developed to study context-sensitivity in low-level vision (e.g. Kóvacs 1996). These include the effects of context on size perception (e.g. Phillips et al 2004), flanker effects on edge-detection (e.g. Polat and Sagi 1993), and contour integration (e.g. Field et al 1993), but cross-cultural studies using these methods are rare. As the underlying processes occur automatically, and cannot be over-ridden by voluntary attentional strategies, the prevailing assumption is that these basic low-level processes are common to all cultures.

Kitayama et al (2003) have shown that reproduction of line-length is more context-sensitive in Japanese than in western cultures. Their task involved inspecting a line drawn within a frame, and drawing a line of the same absolute or relative length within another frame of either the same or a different size. To ensure that low-level perceptual processes, such as iconic memory, played no role the second frame was placed in the opposite corner of the laboratory. The cultural differences that they observed are therefore more likely to have arisen from differences in attention, working memory, or motor control than from any differences in low-level vision.

In the experiments reported here we studied differences between people in Japan and in the UK using a rigorous psychophysical paradigm based on the Ebbinghaus illusion (Phillips et al 2004), as shown in Figs. 1 and 2. This allows the study of the effect of surrounding context on size perception. It has long been thought that such

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- **Deleted:** and then drawing it within another frame of either the same or a different size.
- **Deleted:** A recent study of the Himba, a remote semi-nomadic culture in northern Namibia, suggests that contextual interactions in low-level vision may vary across cultures. They showed significantly less context-sensitivity than people in the UK, as measured by the Ebbinghaus illusion (de Fockert et al 2007). Though suggestive, this study is not conclusive, because group sizes were small (8 in each culture), matching subjects across such widely differing cultures is difficult, and there is no evidence concerning the extent of context sensitivity in the Himba at higher cognitive levels. ¶
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effects are predominantly pre-attentive (e.g. Stuart et al 1993), and involve activity at low levels of the visual pathways. Neuroimaging now provides further support for this view. Using functional MRI, Murray et al (2006) found that activity in the human primary visual cortex (V1) corresponds to the perceived size of objects as influenced by contextual cues, rather than to the retinal size of the object's image. The effect of context on size discrimination is a good candidate for cross-cultural study because, even though it is pre-attentive, it is not fully developed by four years of age (Káldy and Kovács 2003), so there is plenty of time for socialisation to exert an influence. Furthermore, there is evidence that this effect can vary across cultures; a recent study found that the Himba, a remote semi-nomadic culture in northern Namibia, showed less context-sensitivity than people in the UK (de Fockert et al 2007).

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There is also evidence that different cognitive styles are associated with chosen profession. Fathers of autistic boys are more likely to be employed in 'detail focused' professions such as computing, accountancy, and engineering (Briskman et al 2001), and students of sciences in which mathematics is important, such as physics and engineering, report higher autistic spectrum traits than students of the humanities or social sciences (Baron-Cohen et al 2001). These differences have mostly been studied in western cultures, however, so to determine whether there are similar differences in Japan we compared females working in the social sciences with males working in the mathematical sciences. The success of Japanese engineers in global competition raises the possibility that they may be even more analytic, or detail-focussed, than their competitors in the west.

Figures 1 and 2 around here

2 Method

We used a two-alternative forced choice paradigm (Phillips et al 2004) in which the task is to decide whether the centre circle that looks larger is in the 3 x 3 array on the left or in that on the right, and to indicate this by pressing the left or the right arrow on the keyboard. The two centre circles always differed in actual size, and this difference varied in magnitude across trials. Unlike most previous studies, our paradigm includes conditions in which centre-surround contrast enhances size discrimination. Without these conditions participants could respond correctly simply by selecting the array with larger surrounds, so they are needed to unconfound differences in centre size from differences in surround size.

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2.1 *Participants*

In the main experiment, two groups of participants were tested in Japan: females in the social sciences and males in the mathematical sciences. These were 29 female students from the Department of Psychology at Osaka Shōin Women's University, and 34 male engineers. The engineers were 16 professional software or electrical engineers, mostly employed by Toshiba, and 18 mechanical engineering postgraduate students, working in the fluid mechanics laboratory at the Kyōto Institute of Technology. Their performance was compared with that of staff and students working in the University of Stirling in the UK. Of these 16 were females from the Department of Applied Social Science, and 16 were males from the Department of Computing Science and Mathematics. Performance of the two UK groups was included in the report by Phillips et al (2004) where it was shown that there are independent effects of sex and profession. We co-varied them here to obtain cross-cultural comparisons at widely separated points on the within culture spectrum of sensitivity to context. Following the main study, two slightly modified experiments were run using additional female psychology students in Japan and in the UK.

2.2 *Stimuli and experimental design*

On each trial two 3x3 arrays of circles were presented, side by side on a computer screen. The centre circle of one array was 100 pixels in diameter; the centre circle of the other was 2, 6, 10, 14, or 18 pixels larger or smaller. Each of these 10 size differences was presented 8 times, with the larger central circle surrounded by larger circles (125 pixels diameter) and the smaller central circle surrounded by smaller circles (50 pixels diameter). In these conditions size contrast impairs discrimination. If only these conditions were used participants could be correct on every trial simply by choosing the array with larger surrounds, which is easy to see. Therefore, to unconfound relations between surround sizes and centre sizes the 98 and 102 pixel circles were presented eight times each with the smaller centre circle surrounded by circles 125 pixels in diameter and the larger central circle surrounded by circles 50 pixels in diameter. Size contrast then increases accuracy if participants are judging the apparent sizes of the centre circles, but if they choose the array with larger surrounds then they will be wrong on every trial in this condition. The 96 trials [(10 x 8) + (2 x 8)] were presented in random order.

2.3 *Apparatus*

A Java program developed by Phillips et al (2004) was used to present stimuli and record and analyse responses. Stimuli were presented on laptop computers (in the UK on a Toshiba 4090 CDS laptop with a 13-inch screen; in Japan on either a Toshiba

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Dynabook SS M10 11L/2 with a 12-inch screen or a Toshiba Dynabook SS 1620 12L/2 with a 13-inch screen). Screens were set at 800 x 600 pixels resolution.

2.4 *Procedure*

Participants were tested individually in a quiet room. They were shown an example of the stimulus arrays to be used and the task was explained. They were asked to use the cursor keys to indicate which central circle looked larger, irrespective of actual size. They were told that the circles were never the same size, and to guess if they were uncertain. Stimuli were presented for 2 seconds and subsequent trials followed roughly 2 seconds after response. No feedback was given during the 7 minute procedure. The distance between the participant and screen was that normal for laptop operation.

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3 **Results**

We first compare discrimination in the two conditions in which there was a 2% difference in size. In one of these, context was expected to make the size discrimination easier as shown in Fig. 1. In the other, it was expected to make the discrimination harder, as shown in Fig. 2. Only the context distinguishes these conditions so we can be confident that any effects are due to context alone. With helpful context, for Japanese male mathematical scientists discrimination accuracy was 99.8%; with misleading context, it was 3.3%, a highly significant difference (t_{28} = 50.6, $p < 0.001$, $d = 16.30$). For Japanese female social scientists discrimination accuracy was 96.8% with helpful context and 4.6% with misleading context (t_{33} = 66.9, $p < 0.001$, $d = 17.59$). With helpful context, for British male mathematical scientists discrimination accuracy was 97.3%; with misleading context it was 10.2%

($t_{15} = 26.0$, $p < 0.001$, $d = 10.05$). For British female social scientists discrimination accuracy was 96.5% with helpful context and 4.3% with misleading context ($t_{15} = 38.6$, $p < 0.001$, $d = 16.71$).

The large effects of context when the size difference was only 2% show that all subjects were sensitive to context. How sensitive they were is shown by the real size difference needed to overcome the misleading effects of size contrast. The relation between accuracy and the actual size difference for the conditions where context impairs discrimination is shown in Fig 3. Accuracy was low when the real size difference was 2% but much higher when it was 18%, where most, but not all, of the misleading effects of context have been overcome. Clearly, a larger real size difference is needed to overcome the effects of context in Japan than in the UK.

Figure 3 around here

Overall context-sensitivity can be quantified by the total number of correct responses out of the 80 trials, incorporating all 5 size differences for the conditions in which context impairs discrimination. This measure increases as context-sensitivity decreases. The distributions of individual scores on this measure are shown in Fig. 4. Though there were clear individual differences within groups and some large overlaps between groups, for some group comparisons there was little overlap. In Japan, 25 out of 29 female social scientists scored less than 40 correct out of 80 overall, compared with only 1 out of 16 UK male mathematical scientists.

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Figure 4 around here

A 2-way ANOVA of total score showed a main effect for culture, $F(1, 3) = 27.2$, $p < 0.001$, $\eta_p^2 = 0.23$, and a main effect for sex/discipline, $F(1, 3) = 11.3$, $p = 0.001$, $\eta_p^2 = 0.11$. There was no interaction, $F(1, 3) = 0.045$, $p = 0.83$, $\eta_p^2 = 0.00$. Planned t-tests showed a significant difference between the 2 cultural groups: $t(93) = 4.842$, $p < 0.001$, $d = 1.08$. There were also significant differences within each culture between the male mathematical scientist and female social scientist groups: for the two British groups, $t(30) = 2.59$, $p = 0.015$, $d = 0.92$; for the two Japanese groups, $t(61) = 2.53$, $p = 0.014$, $d = 0.65$. The only non-significant comparison between individual groups was between British female social scientists and Japanese male mathematical scientists, $t(48) = 1.22$, $p = 0.228$, $d = 0.39$.

The above results do not tell us how participants in Japan perform with real size differences greater than 18%. It may be that there is some difference between cultures that produces lower accuracy in Japan at all real size differences. To explore this we gave a new set of 16 Japanese female social science students the same task, but using real differences up to 28%, in steps of 6%. Discrimination rose to a level just below 100% at size differences of about 22%, as compared to about 14% in the UK. The rate at which discrimination rises to this level, which primarily reflects response reliability, seems to be much the same in the two cultures. What differs is not response reliability but the amount of real size difference required to overcome the misleading effects of context.

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In the above experiments participants were asked to say which of the two centre circles 'looked larger', irrespective of their actual size. It is possible that interpretation of this instruction varies across cultures. To explore this we tested new participants in both Japan and the UK. In Japan 25 further female psychology students were tested in Osaka Shōin Women's University. The task was exactly as before, except that the instructions were modified to encourage participants to try to 'see through' the illusion. They were told that the stimuli were examples of a well-known illusion, and that they were to judge which of the central circles was 'really larger' irrespective of which 'looked larger'. Twenty female psychology students studying at Stirling University in the UK were also tested: 10 were asked to select the centre circle that 'looked larger'; the other 10 were asked to select that which was 'really larger', just as in Japan. The results show that for both cultures there were large effects of context even when subjects were warned about its illusory effects. In Japan the mean score out of 80 across all conditions where context was misleading was 23.3 for the 'looks larger' instruction, and 29.7 for the 'really is larger' instruction. In the UK the mean scores for these two instruction conditions were 30.6 and 40.4, respectively. This contrasts with scores of more than 95% correct for all groups when context is helpful. A 2-way ANOVA of these scores out of 80 was performed to compare the new results from the UK with those from Japan. There was a main effect for culture, $F\ (1, 3) = 7.263$, $p = 0.009$, $\eta_p^2 = 0.094$, and a main effect of instruction condition, $F\ (1, 3) = 5.857$, $p = 0.018$, $\eta_p^2 = 0.077$. There was no interaction, $F = 0.257$, $p = 0.614$, $\eta_p^2 = 0.004$. These results show the effect of culture to be robust. They indicate that the cultural differences are not due to different interpretations of the instructions, and they provide further evidence that participants cannot voluntarily ignore the context.

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4 General discussion

These results are evidence that size perception is more context-sensitive in Japan than in the UK. They extend the evidence for cultural differences at higher levels of cognition and perception (e.g. Nisbett and Masuda 2003; Nisbett and Miyamoto 2005) to specifically include contextual interactions that occur at lower levels in the visual processing hierarchy.

Nisbett et al (2001) argue that cognition may be far less universal across cultures than is often assumed. Our results show the importance of both commonalities and differences across cultures. The contextual interactions producing size contrast occurred in every individual tested in both cultures. Nevertheless, there was great variation in the strength of those interactions. Thus, the cultural difference does not involve the use of context in some all-or-none fashion. At higher cognitive levels it might be possible for there to be 'context-independent' cultures, as suggested by Nisbett and Miyamoto (2005), but at the level of size contrast all cultures are 'context-dependent'. In some cultures this dependence is large; in others it is very large. Furthermore, as we found differences across sex and profession within each culture, this emphasises the importance of careful participant matching in cross-cultural research.

On present data we cannot rule out the possibility of a genetic influence on the demonstrated cross-cultural differences. However, we are inclined to explain the differences in terms of culture-specific patterns of attention. Nisbett and Masuda (2003) suggest that cultural differences in perception derive predominantly from differences in attention. If these differences existed simply at the level of moment-to-moment attentional focus, they could not explain our findings. In our size perception task all subjects attended to the relative size of the centre circles, and used that to determine response. Otherwise discrimination could not have been near 100% on trials where the surrounding context made the real size difference seem larger than it was. However, context must also have had a large effect on all trials, because discrimination was near 0% for the same real size difference when context made the relative sizes seem to be the opposite of what they really were. Thus on all trials both target and context influenced response. No observer could choose to ignore relations between centre and surround circles, even though they all attended to and judged the relative sizes of the centre circles. Furthermore, modifying the instructions so as to encourage participants to ignore the surrounds had the same effect in both cultures. Thus, cultural differences in this paradigm do not arise from short-term differences in patterns of attention.

Nevertheless, it is likely that there are attentional effects in this task (Shulman, 1992), and furthermore there is extensive evidence for attentional effects throughout all levels of the visual system. We suggest that chronic differences in the pattern of attention between cultures may affect low-level vision through activity-dependent synaptic plasticity. We now need to discover the origins of these cultural differences in low-level vision. Differences in cultural practices and in their physical environments both make large contributions to differences in context-sensitivity at the higher levels of perception and cognition (Miyamoto et al 2006). The present study suggests that they may also influence low-level processes.

Acknowledgements. We thank Jules Davidoff, Nick Humphrey, and Helen Ross for expert commentaries on an earlier version of this paper. We also thank the Departments of Psychology at Stirling University and the Osaka Shoin Women's University for supporting our research.

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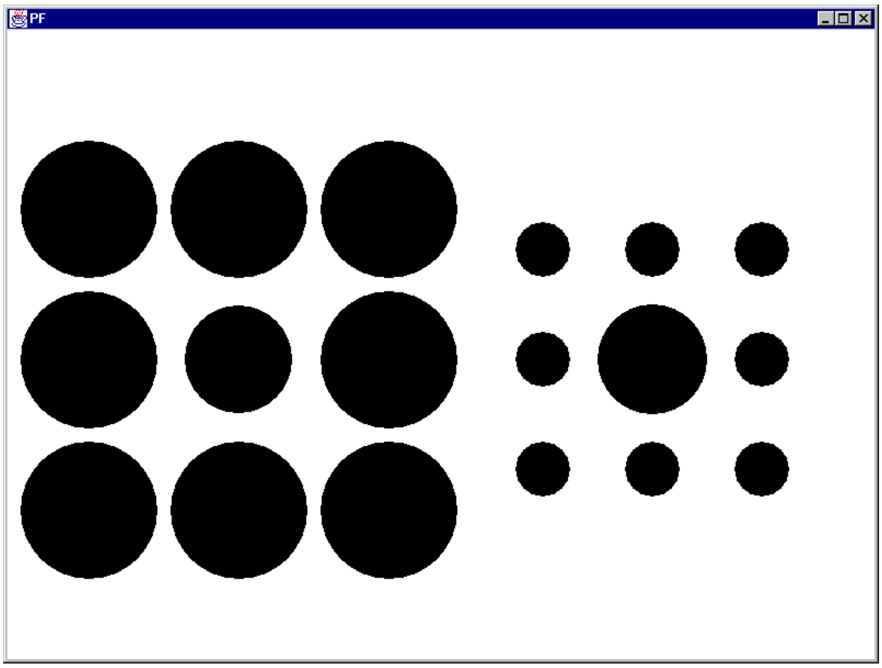

Fig. 1. An example of the stimulus display used in conditions where size contrast enhances size discrimination. The centre circle on the right is 2% larger than that on the left. Here it is surrounded by smaller circles which make it look larger than it is, whereas that on the left is surrounded by larger circles, which make it look smaller than it is. It is therefore easy to see that the centre circle on the right is larger than that on the left.

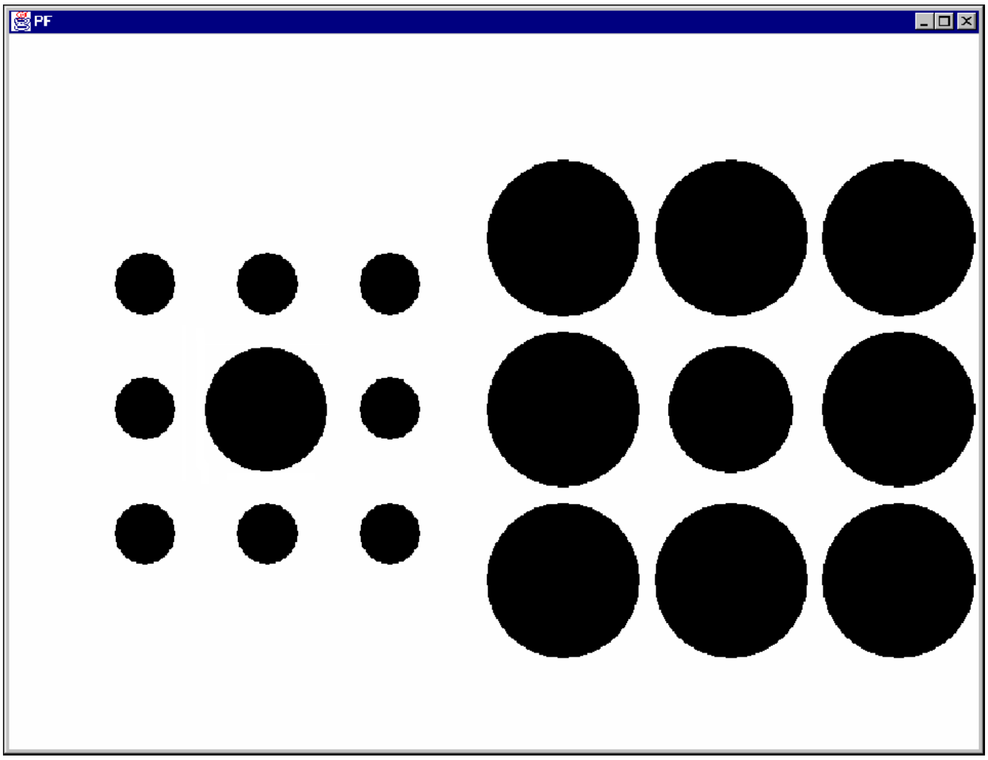

Fig. 2. An example of the stimulus display used in conditions where size contrast impairs size discrimination. The centre circle on the right is 2% larger than that on the left, exactly as in Fig. 1, but here it is surrounded by larger circles, whereas that on the left is surrounded by smaller circles. As the effects of size contrast oppose the real size difference they make it hard to see, and can make the centre circle on the left seem to be larger than that on the right.

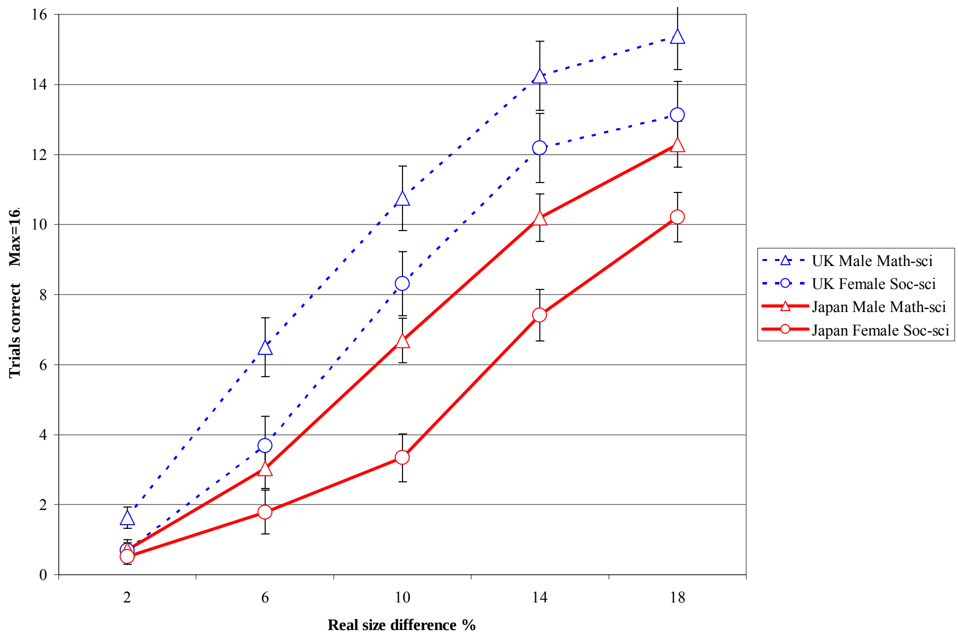

Fig. 3. Mean accuracy of size discrimination as a function of the real size difference for the conditions where context impairs discrimination. The performance found in the UK is shown in dotted lines for comparison with that found in Japan, which is shown in solid lines. Standard errors are shown by the error bars around each mean.

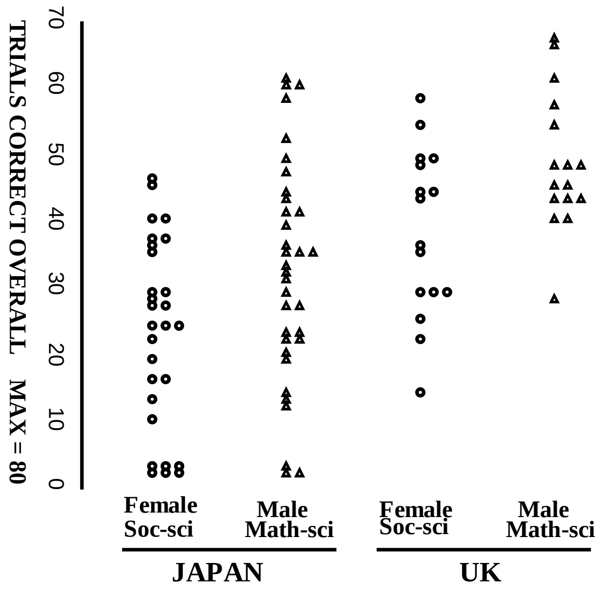

Fig. 4. The distribution of individual total accuracy scores across all real size differences combined in conditions where the context impairs discrimination. Each triangle is a male in the mathematical sciences. Each circle is a female in the social sciences.

4 General discussion

These results are evidence that size perception is more context-sensitive in Japan than in the UK. They extend the evidence for cultural differences at higher levels of cognition and perception (e.g. Nisbett and Masuda 2003; Nisbett and Miyamoto 2005) to specifically include contextual interactions that occur at lower levels in the visual processing hierarchy.

Nisbett and Masuda (2003) conclude that cultural differences in perception derive predominantly from differences in attention. In our size perception task all subjects attended to the relative size of the centre circles, and used that to determine response. If not then discrimination could not have been near 100% on trials where the surrounding context made the real size difference seem larger than it was. However, context must also have had a large effect on all trials, because discrimination was near 0% for the same real size difference when context made the relative sizes seem to be the opposite of what they really were. Thus on all trials both target and context influenced response. No observer could choose to ignore relations between centre and surround circles, even though they all attended to and judged the relative sizes of the centre circles. Furthermore, modifying the instructions so as to encourage participants to ignore the surrounds had the same effect in both cultures. Thus, cultural differences in this paradigm do not arise from differences in the stimuli or relations that are selected to influence response. Nevertheless, there may still be some attentional effects in this task (Shulman 1992), and this is likely given the extensive evidence for attentional effects throughout all levels of the visual system. However, if there are, then they modulate contextual interactions that affect activity at low levels in the hierarchy of visual processing.

Nisbett et al (2001) argue that cognition may be far less universal across cultures than is often assumed. Our results show the importance of both commonalities and differences across cultures. The contextual interactions producing size contrast occurred in every individual tested in both cultures. Nevertheless, there was great variation in the strength of those interactions. Thus, the cultural difference does not involve the use of context in some all-or-none fashion. At higher cognitive levels it might be possible for there to be 'context-independent' cultures, as suggested by Nisbett and Miyamoto (2005), but at the level of size contrast all cultures are 'context-dependent'. In some cultures this dependence is large; in others it is very large.

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Japanese engineers have a perceptual style that is about as context-sensitive as that of females working in the social sciences in the UK. Thus, a highly context-sensitive, or analytic, perceptual style seems not to be necessary for success in engineering professions. This raises the possibility that Japanese success in engineering arises more from better social organization than from the individual cognitive style of those in the profession.

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Furthermore, as we found differences across sex and profession within each culture, this emphasises the importance of careful participant matching in cross-cultural research.

We now need to discover the origins of these cultural differences in low-level vision. Differences in cultural practices and in their physical environments both make large contributions to differences in context-sensitivity at the higher levels of perception and cognition (Miyamoto et al 2006). thatmay also synaptic

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, such as those studied here, possibly through effects on attention, which affect low-level visual processes, and which thus could affect low-level vision through activity-dependent plasticity

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Genetic contributions to the differences found here are also possible, and should be taken seriously as, in addition to the sex differences, it has been shown that the c

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greatly weakened in both disorganized schizophrenia (Uhlhaas and Silverstein 2005) and autism (Happé 1999).

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Strikingly, in both pathologies, performance in this task is supra-normal, rather than sub-normal, because the task is designed so that, atypically, context is misleading. It is not yet known whether a cultural bias toward high context-sensitivity is protective or detrimental in these disorders, so cross-cultural comparisons such as those made here may provide useful information on this issue.

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The findings reported here are limited in several ways. More professions could have been compared. Furthermore, we studied only one form of context-sensitivity in low-level vision. Others now need to be examined, including tasks where the use of context enhances rather than degrades performance. Here, we have also provided no cross-cultural developmental data for this form of context-sensitivity, nor any evidence of cultural differences in the underlying neuronal interactions. All of these limitations can be overcome by combining the rigorous methods of psychophysics and cognitive neuroscience with cross-cultural comparisons.

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The results reported above may encourage the further development of such a cross-cultural psychophysics, because although the basic underlying contextual interactions occurred in all cultures, their strength varied greatly both within and between cultures.