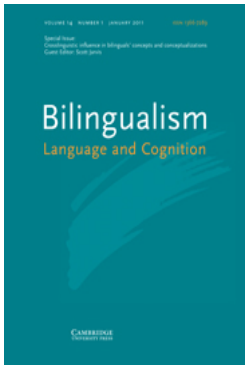

Representation of colour concepts in bilingual cognition: The case of Japanese blues

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Representation of colour concepts in bilingual cognition: The case of Japanese blues*

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Previous studies demonstrate that lexical coding of colour influences categorical perception of colour, such that participants are more likely to rate two colours to be more similar if they belong to the same linguistic category (Roberson et al., 2000, 2005). Recent work shows changes in Greek–English bilinguals' perception of within and cross-category stimulus pairs as a function of the availability of the relevant colour terms in semantic memory, and the amount of time spent in the L2-speaking country (Athanasopoulos, 2009). The present paper extends Athanasopoulos' (2009) investigation by looking at cognitive processing of colour in Japanese–English bilinguals. Like Greek, Japanese contrasts with English in that it has an additional monolexemic term for 'light blue' (mizuiro)*. The aim of the paper is to examine to what degree linguistic and extralinguistic variables modulate Japanese–English bilinguals' sensitivity to the blue/light blue distinction. Results showed that those bilinguals who used English more frequently distinguished blue and light blue stimulus pairs less well than those who used Japanese more frequently. These results suggest that bilingual cognition may be dynamic and flexible, as the degree to which it resembles that of either monolingual norm is, in this case, fundamentally a matter of frequency of language use.*

Keywords: bilingual cognition, Whorf, linguistic relativity, colour perception

1. Introduction

From Homer and Herodotus, to the German Romantic philosophers of the nineteenth century, and to Einstein and Vygotsky in the early twentieth century, the view has been expressed, in one form or another, that the way we conceptualize reality and the world around us is tightly linked to the language and culture we are exposed to from birth (see Athanasopoulos, 2009; Hunt & Agnoli, 1991; Lucy, 1992, for historical references). In 1940, the chemical-engineer-turned-linguist Benjamin Lee Whorf elegantly expressed what he called the "linguistic relativity principle", which states that "users of markedly different grammars are pointed by their grammars toward different types of observations and different evaluations of externally similar acts of observation, and hence are not equivalent as observers but must arrive at somewhat different views of the world" (Whorf, 1940/1956, p. 221). Since then, Whorf's principle has been reformulated in various guises, most frequently stated as a "hypothesis" with a "strong version" (language shapes, determines and constrains thought) and a "weak version" (language highlights certain aspects of reality more than others). These different hypotheses have generated vigorous debate in the fields of linguistics, anthropology, philosophy and psychology and have sometimes elicited passionate criticism and rejection: "But it is wrong, all wrong. The idea that thought is the same thing as language is an example of what can be called a conventional absurdity" (Pinker, 1995, p. 57).

Despite passionate opinions, views and critiques of Whorf's principle, empirical evidence from the past fifteen years or so has indeed shown that at least for some domains, speakers of different languages do evaluate perceptual distinctions differently. Colour perception has been a traditional test case of the Whorfian principle of linguistic relativity (Berlin & Kay, 1969; Brown & Lenneberg, 1954; Heider & Olivier, 1972; Kay & Kempton, 1984; Roberson, 2005; Rosch-Heider, 1972). The vast majority of empirical research to date has supported the notion that language acts as an attention-directing mechanism for the purposes of colour discrimination and categorization. Studies have shown that participants are more likely to judge two colours to be more similar if they share the same name in their respective language rather than on the basis of the objective perceptual distance between them in colour space (Davidoff, Davies & Roberson, 1999; Roberson, Davidoff, Davies & Shapiro, 2005;

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Roberson, Davies & Davidoff, 2000; Kay & Regier, 2006, 2007). Moreover, such effects become apparent in children around the same time they begin to acquire their respective language's colour vocabulary (Roberson, Davidoff, Davies & Shapiro, 2004).

More recent studies have demonstrated Whorfian effects online. In a speeded colour discrimination task, where participants had to decide which colour was the odd one out in a triad of colour stimuli, Russian speakers were faster to discriminate between a light and a dark shade of blue than English speakers, presumably because Russian makes an obligatory lexical distinction between two shades of blue whereas English does not (Winawer, Witthoft, Frank, Wu, Wade & Boroditsky, 2007). Importantly, the categorical perception effect found in the Russian speakers was abolished when individuals rehearsed covertly a string of digits but not when they memorized a grid pattern of black and white squares. This finding supports previous studies that have demonstrated that verbal interference abolishes categorical perception effects (Roberson & Davidoff, 2000).

1.1 Bilingualism and thought

Early studies on bilingual semantic representation demonstrated semantic shifts of colour category prototypes. Caskey-Sirmons and Hickerson (1977) showed that individuals from five different language backgrounds, including Japanese, who were all bilingual in English, had shifted their prototypes for a range of L1 colour terms towards the English prototypes. This led the researchers to claim that "the worldview of bilinguals, whatever their first language, comes to resemble, to some degree, that of monolingual speakers of their second" (Caskey-Sirmons and Hickerson 1977, p. 365; see also Ervin, 1961). Zollinger (1988) showed that Japanese children living in Germany used certain L1-specific colour terms significantly less frequently than Japanese children living in Japan. Jameson and Alvarado (2003) found that bilingual speakers whose L1 (Vietnamese) has fewer colour terms than their L2 (English) tended to modify their colour naming behaviour according to the distinctions made in their L2, suggesting that bilinguals use whichever system is maximally informative. These studies have shed considerable light on the semantic nature of words in the bilingual lexicon, and have provided a stepping-stone for recent studies on conceptual representation.

Inspired by the recent advances in the investigation of the linguistic relativity principle, Green (1998), Pavlenko (1999, 2005) and Jarvis and Pavlenko (2008) have pointed out the potential of non-verbal investigative techniques such as similarity judgments in elucidating the nature of conceptual representation in bilinguals. This has in turn yielded further advancements in our understanding of the linguistic relativity principle. Specifically, bilingual speakers whose languages encode reality in different ways tend to display variable cognitive behaviour, sometimes resembling monolingual speakers of their L1, sometimes resembling monolingual speakers of the L2, but most times falling somewhere in-between. Determining the underlying causes of different degrees of bilingual cognitive shift is the challenge that the new study of bilingualism and thought is faced with.

To date, the question has been addressed, to some extent, in the domain of grammatical number marking. Cook, Bassetti, Kasai, Sasaki and Takahashi (2006) showed effects of length of stay in the L2-speaking country on the way Japanese–English bilinguals extended the novel name for a target object or substance to a shape or material alternate. Those bilinguals who had stayed in the UK for more than three years shifted their name-extension preferences towards those of monolingual speakers of English. On the other hand, those bilinguals who had stayed in the UK for less than three years displayed a pattern that was more similar to that displayed by Japanese monolinguals. Athanasopoulos (2006, 2007) and Athanasopoulos and Kasai (2008) found that increasing proficiency in the L2 was the best predictor of the degree to which Japanese–English bilinguals shifted their similarity judgments of countable objects and non-countable substances towards those of monolingual speakers of English.

Athanasopoulos (2009) systematically investigated the consequences of bilingualism on perception and cognitive representation of colour categories. Based on the observation that Greek differentiates the blue region of colour space into *ble* ('blue') and *ghalazio* ('light blue'), Athanasopoulos (2009) asked Greek–English bilinguals to judge the similarity or difference between light and dark blue colour stimuli. The study measured a range of variables characterizing the bilingual person, such as general L2 proficiency, semantic memory of the specific L1 and L2 terms under investigation, the amount of time bilinguals spend using their L2, their age of L2 acquisition, and the amount of time they had stayed in the L2-speaking country. Results showed that the factors affecting the degree to which bilinguals judged the perceptual difference between different shades of blue depended on how salient the terms *ble* and *blue* were in semantic memory (i.e., how high they appeared on a list of colour terms participants were required to produce as quickly as possible), and on the amount of time they had lived in the UK. The less salient *ble* was, and the more salient *blue* was, and the more bilinguals had stayed in the UK, the less they differentiated between the different shades of blue in their similarity judgments. Importantly, these variables were found to independently predict bilingual behaviour, as each variable was correlated with bilinguals' similarity judgments while partialling out all the other variables.

These studies help to shed light on an important issue in the language and thought debate, namely the question of whether it is language per se rather than extralinguistic cultural variables that may affect human cognition. Because of the dynamic nature of bilingualism, it is possible to directly investigate effects of several types of variables on the changing linguistic and cognitive state of the bilingual person. We see the results obtained by Cook, Athanasopoulos and their colleagues as complementary rather than contradictory. They point to the synergistic influence of BOTH linguistic competence AND sociocultural immersion on the bilingual mind. Studies from other domains support this view, but they also show that on balance, it is linguistic rather than sociocultural variables that exert greater effect on the cognitive performance of bilingual speakers. For example, a study of grammatical gender and picture similarity judgments in a group of Spanish–German bilinguals revealed a strong relationship between similarity scores and language proficiency, age of acquisition, and length of language use (Boroditsky, Schmidt & Phillips, 2003; see also Bassetti, 2007). Brown and Gullberg (2008) showed that Japanese–English bilinguals shifted their gesture behaviour towards the English pattern even when they were living and tested in Japan. Dewaele (2004) found that self-rated proficiency in a language and frequency of use of a language significantly predicted perception of emotional force of swear words in multilinguals. A synthesis of available studies to date suggests an inextricable link between language, culture and cognition, and point to the conclusion that the precise relationship between these constructs might be more complex than previously thought.

1.2 Aims of the current study

Colour perception presents an ideal test case of the nature of bilingual concepts. This is because languages vary widely in where they place boundaries between colour categories on colour space. Investigating bilinguals whose languages offer distinct partitions of a physical continuum speaks directly to the question of how language-specific concepts are reconciled in bilingual cognition. Here, we aim to extend that investigation by conducting a preliminary study that looks into the way Japanese–English bilinguals evaluate perceptual distinctions of dark and light blue stimuli. Like Russian (Winawer et al., 2007), Turkish (Özgen & Davies, 1998) and Greek (Athanasopoulos, 2009), Japanese divides the blue region of colour space into a darker shade called *ao* and a lighter shade called *mizuiro* (Uchikawa & Boynton, 1987). Given the established effects of lexical partition of the blue area of colour space in Greek and Russian speakers, extending the investigation to a non-Indo-European language such as Japanese will provide a more complete picture of the observed phenomenon, and increase our knowledge of the extent of the influence of linguistic diversity on cognition.

From a bilingualism viewpoint, our goal is to shed more light on the relative impact of linguistic and sociocultural variables on colour cognition in bilinguals. What remains unclear when considering the influence of culture on cognition is the qualitative nature of specific cultural elements that may modulate cognition. To be more precise, differences in cognitive patterns between populations are readily explained as the function of specific linguistic categories, be it lexical (colour) or grammatical (number). An alternative explanation based on, say, culture, leaves open the interpretation of cognitive patterns, depending on one's view of what exactly constitutes "cultural exposure". Athanasopoulos (2009) speculated that the finding of concurrent influence of semantic memory for specific lexical items and length of stay in the UK is best interpreted as fundamentally a matter of USE of specific colour terms. In other words, living in a particular country, or sociocultural setting, might reinforce the use of specific linguistic categories, but it is ultimately the increasing (or decreasing in the case of L1 attrition in memory) use of specific linguistic categories itself that directly influences cognition. One alternative possibility is to interpret the effect of length of stay as a matter of increasing visual expertise. If one assumes that the visual diet of the UK is different from that of Greece, then one could conjecture that the "long-stay" Greeks in Athanasopoulos' (2009) study did not distinguish between light and dark blues as much as their "short-stay" peers because they had been living long enough in a country (UK) where visual exposure to different or more subtle shades of blue is substantially less compared to their native Greece. Such an explanation is not implausible, but it is very difficult to verify, as measuring each individual's exposure to different blues is nearly impossible. But if subsequent studies found effects of length of stay in a particular country whilst controlling for all other possible variables, then the visual diet hypothesis would be somewhat more substantiated.

The current study tests categorical perception of colour in late bilinguals who have attained a high level of proficiency in the L2. Based on previous studies, which found a positive correlation between L2 proficiency and cognitive shift, even when controlling for age of acquisition and other extralinguistic variables, we can hypothesize that these advanced bilinguals will resemble, to some extent, monolingual speakers of their L2 when they evaluate perceptual distinctions of colours. By keeping proficiency and age of acquisition constant, we aim to penetrate deeper into the converging cultural elements that may modulate bilingual conception of reality. Specifically, it may be the case that once advanced bilinguals have shifted cognitively towards the L2, their cognition becomes fossilized and remains permanently

altered and static. On the other hand, advanced bilinguals may still display cognitive flexibility, indicating that they can still "behave" in an L1-like way, depending on linguistic and/or sociocultural variables. Thus the advanced bilinguals in this study will have a wide range of length of stay in the UK, and a wide range of how frequently they use each of their languages in order to communicate. We also manipulated testing context, such that some bilinguals were tested in Japanese by a Japanese native speaker, and some were tested in English by a non-Japanese speaker. Prior to testing, participants were engaged in small talk in the relevant language in order to try to induce the relevant language mode (Grosjean, 1998).

2. Method

2.1 Participants

Twelve monolingual Japanese speakers (8 females, 4 males, mean age 26 years old, SD = 4), 15 monolingual English speakers (8 females, 7 males, mean age 24 years old, SD = 5), and 27 Japanese–English bilingual speakers (19 females, 8 males, mean age 27 years old, SD = 5) were recruited from and tested at the University of Essex in the UK. The Japanese monolingual participants were selected from a larger pool of potential participants who had just arrived in the UK to attend an English summer school. These 12 participants were selected after consultation with their English language tutors. None of them had stayed in the UK or another English-speaking country for more than two weeks. In addition, they were given the Nation vocabulary test which measures vocabulary in English at five levels and can be used as an indicator of overall language proficiency (see, e.g., Athanasopoulos, 2009; Cook et al., 2006). Their mean score on the test was 49/90, SD = 3. The majority of these participants self-reported that their proficiency in English was 'Poor' or 'Basic' on a 4-point scale that included the categories 'Poor', 'Basic', 'Intermediate' and 'Advanced'. These participants were all University students in Japan, studying non-English language related subjects.[1] Since Japanese commonly uses two distinct terms to differentiate between two different shades of blue, we expected these participants, with minimal English proficiency and length of stay in an English-speaking country, to judge members of pairs of stimuli that cut across the *ao/mizuiro* boundary as more different than members of pairs that fall within each category boundary.

The Japanese–English bilingual participants all had Japanese as their native language and had started learning English as a second language at a mean age of 12 (SD = 0.6, range 10–13) years old. Their proficiency in English was measured by the Nation vocabulary test. Their mean score was 76/90 (SD = 4, range 70–88). Their mean length of stay in the UK was 38 months (SD = 33 months, range 2–114 months). They reported that they used English 57% of the time, on average, in their daily activities (SD = 22, range 15–100) and Japanese 43% of the time (SD = 22, range 0–85). They were all undergraduate or postgraduate students in the UK. The measures above were elicited by means of a questionnaire, and were recorded in order to be used in correlational analyses with bilinguals' similarity judgments.

The English monolingual participants were undergraduate and postgraduate students in the UK. Since English generally uses a single term to refer to the blue area of colour space, English speakers are expected to treat pairs of stimuli that cut across the *ao/mizuiro* boundary no differently from pairs that fall within each category boundary. All participants reported that they had normal colour vision, and were rewarded for their participation.

2.2 Materials

A total of 10 colour stimuli were used from a range supplied by the Color-Aid Corporation (www.coloraid.com). The selected stimuli came from the Blue (B) and Cyan Blue (C) Hue range, and varied across 6 levels of lightness, called 'Hue', 'Tint 1' (T1), 'Tint 2' (T2), 'Tint 3' (T3), 'Tint 4' (T4) and 'Light Tint' (LT), going from darkest to lightest. Color-aid codes for each stimulus are expressed in the form Hue/Lightness. The stimuli we used were: B/T1, B/T2, B/T3, B/T4, C/Hue, C/T1, C/T2, C/T3, C/T4 and C/LT. These stimuli were consistently named *ao* or *mizuiro* by 17 Japanese monolinguals from Athanasopoulos, Sasaki and Cook's (2004) naming database (the criterion we used for selecting these stimuli was within-group naming agreement of at least 80% for each stimulus). The stimuli were mounted on 40 mm square pieces of white card. They were then organized into within and cross-category pairs, and into "near-colour" and "far-colour" comparisons. Within-category pairs were constructed so that both members were named either *ao* or *mizuiro*. Cross-category pairs were constructed so that one member of the pair was called *ao* and the other *mizuiro*. Near-colour pairs included stimuli with a perceptual distance of 1 lightness step, while far-colour pairs included members with a perceptual distance of 2 lightness steps. For near-colours, the within-category pairs constructed were B/T1–B/T2, and B/T3–B/T4. The cross-category pair was B/T2–B/T3. For far-colours, the within-category pairs

[1] Because Japanese children are exposed to English from the age of 12 in their national curriculum, it is nearly impossible to find Japanese speakers who are both completely monolingual and also educated to university level. We use the term "monolingual" by convention here to refer essentially to individuals who might best be described as functional monolinguals with minimal English proficiency (see also Athanasopoulos, 2006; Athanasopoulos & Kasai, 2008).

Table 1. *Mean similarity judgments (and standard deviations) of cross-category and within-category, near-colour and far-colour pairs of stimuli for the three groups. Figures have been rounded to the nearest 2 decimal places.*

	Near colours		Far colours	
	Within	Cross	Within	Cross
Japanese monolinguals	2.02 (.82)	1.88 (.57)	2.98 (1.14)	3.60 (1.10)
Bilinguals	2.25 (1.16)	2.13 (1.12)	3.72 (2.21)	4.03 (2.22)
English monolinguals	2.38 (.47)	2.50 (.76)	3.87 (.97)	3.72 (1.03)

constructed were C/T2–C/T4 and C/T3–C/LT. The cross-category pairs were C/Hue–C/T2 and C/T1–C/T3.

2.3 Procedure

Each participant was seated at a table with natural daylight coming through a large window and pairs were presented one at a time, in random order. Stimuli subtended approximately 2° of visual angle. Viewing conditions were identical for all three groups. Participants were asked to judge "how different or similar these two colours are" using a 10-point scale where 10 represents maximum dissimilarity and 1 represents maximum similarity. Each pair was shown twice, counterbalancing the position of each individual stimulus in the pair. All participants were tested in the UK. Each testing session lasted for about 40 minutes for bilinguals, and about 15 minutes for Japanese and English monolinguals. The order of tasks for bilinguals was as follows: first, participants conducted the similarity judgment task (10 minutes). Then they completed the personal information questionnaire (5 minutes). Then the colour list for one language was elicited (5 minutes). Then the Nation test was administered (15 minutes). Finally the colour list for the other language was elicited (5 minutes). The English and Japanese monolinguals were given the similarity judgment task, followed by the personal information questionnaire. All monolinguals received instructions in their native language. Eleven bilinguals were given instructions in Japanese by a native Japanese speaker, and 16 bilinguals were given instructions in English by a near-native English speaker who did not speak Japanese. Language of instruction was entered as a variable in the correlational analyses to determine if it has any effect on bilinguals' similarity judgments (see "Results" section).

3. Results

Table 1 shows the mean similarity judgments of cross-category and within-category, near-colour and far-colour pairs of stimuli for the three groups. A 3 (Group: English monolinguals vs. Japanese monolinguals vs. Bilinguals) × 2 (Pair type: Within vs. Cross) × 2 (Distance: near colour vs. far colour) mixed ANOVA showed that the main effects of Group and Pairtype were not significant ($F(2,51) = 0.59$, $p > .05$, $\eta^2 = .02$ and $F(1,51) = 2.30$, $p > .05$, $\eta^2 = 0.04$, respectively). The main effect of Distance was significant ($F(1,51) = 104.59$, $p < .01$, $\eta^2 = .67$). Crucially, the three-way interaction (Group × Pair type x Distance) was statistically significant ($F(2,51) = 6.13$, $p < .01$, $\eta^2 = .19$). This means that there are differences between the groups in how they judge the difference between within- and cross-category pairs across different perceptual distances.[2]

To probe this interaction further, separate repeated measures ANOVAs were conducted for each group, with the factors of Pair type and Distance. For the Japanese monolinguals, there was no significant main effect of Pair type ($F(1,11) = 3.21$, $p > .05$, $\eta^2 = .23$), but the main effect of Distance was significant ($F(1,11) = 25.41$, $p < .01$, $\eta^2 = .70$). The interaction was also significant ($F(1,11) = 10.05$, $p < .01$, $\eta^2 = .48$). Planned comparisons *t*-tests showed that for near-colours, Japanese monolinguals did not distinguish significantly between within- and cross-category pairs ($t(11) = .83$, $p > .05$); however, for far-colours, the difference between within and cross-category pairs was significant ($t(11) = -3.36$, $p < .01$).

For the English monolinguals, the main effect of Pair type was not significant ($F(1,14) = 0.02$, $p > .05$, $\eta^2 = 0$). There was a significant main effect of Distance ($F(1,14) = 79.94$, $p < .01$, $\eta^2 = .85$), but the interaction was not significant ($F(1,14) = 2.15$, $p > .05$, $\eta^2 = .13$). Planned *t*-tests showed that the English monolinguals did

[2] Given that studies show gender-linked differences in colour term use (see, e.g., Arthur, Johnson & Young, 2007), we performed a 2 (Gender) × 2 (Pair type) × 2 (Distance) mixed ANOVA. This revealed a non-significant three-way interaction ($F(1,52) = 3.15$, $p > .05$), and gender did not interact with any of the second-order interactions (Gender × Pair type: $F(1,52) = 3.05$, $p > .05$; Gender × Distance: $F(1,52) = 0.61$, $p > .05$). The main effect of gender was significant ($F(1,52) = 5.08$, $p < .05$), but this does not affect the claims of the current study as gender does not interact with the other variables. The cross-linguistic differences observed cannot be attributed to gender differences.

not distinguish between within- and cross-category pairs in either near-colour comparisons ($t(14) = -.86, p > .05$), or far-colour comparisons ($t(14) = .88, p > .05$).

For the Japanese–English bilinguals, there was no significant main effect of Pair type ($F(1,26) = .97$, $p > .05$, $\eta^2 = .04$). The main effect of Distance was significant ($F(1,26) = 55.65$, $p < .01$, $\eta^2 = .68$). The interaction was also significant ($F(1,26) = 7.04$, $p < .05$, $\eta^2 = .21$). Planned *t*-tests showed that for near-colour comparisons, Japanese–English bilinguals did not distinguish significantly between within- and cross-category pairs ($t(26) = 1.59, p > .05$). The difference between within- and cross-category pairs in far-colour comparisons approached but did not quite reach significance ($t(26) = -1.94, p = .06$). This finding suggests that the Japanese–English bilinguals do not cognitively observe their native colour distinction as readily as Japanese monolinguals. Yet they do not quite resemble English monolinguals either. Their cognitive pattern as a group seems to be between that of the two monolingual groups. To further probe this pattern, correlational analyses were conducted, correlating similarity judgments for far-colours (since near-colours did not yield any significant differences between the groups) with all the linguistic and sociocultural variables that were measured for the bilinguals.

3.1 Identifying the variables that may predict bilingual behaviour

For the correlational analyses, a new variable was created, called the Categorical Perception Index (CPI; Athanasopoulos, 2009). This was calculated by subtracting each participant's mean similarity judgment score for far-colour within-category pairs from their mean similarity judgement score for far-colour cross-category pairs.[3] The greater the resulting score, the more distinction is made between within- and cross-category pairs. This was correlated with each bilingual's score on the Nation vocabulary test, their length of stay in the L2 country, their amount of L2 use (the amount of L1 use was 1 minus the amount of L2 use, since participants were asked what proportion of their daily activities is conducted in the L2 and what proportion in the L1), and the experimental setting that participants were in (i.e., whether they were given task instructions in Japanese by a native Japanese speaker or in English by a near-native English speaker who did not speak any Japanese). CPI correlated significantly only with amount of L2 use ($r = -.54$, $p < .01$). This means that the more bilinguals use English in their daily interactions (and the less they use Japanese), the less distinction they make between within- and cross-category pairs.

4. Discussion

We found that Japanese monolinguals judged two colours to be less similar if they fell into different linguistic categories in Japanese (one *ao* and the other *mizuiro*) than if the two colours were from the same category (both *ao* or both *mizuiro*). Furthermore, perceptual distance between colours modulated this effect, such that the influence of language was only apparent for stimuli that were further apart perceptually, but not for stimuli that were very close perceptually. English monolinguals tested with the identical stimuli did not show categorical perception under any condition. Japanese–English bilinguals displayed a cognitive pattern that was "in-between" the two monolingual groups, suggesting that knowledge of two languages with contrasting ways of parsing reality has profound consequences for cognition. Subsequent analyses showed that frequency of language use correlated with the degree to which bilinguals resembled either monolingual pattern. These results provide some support for Whorf's principle of linguistic relativity, namely that linguistic categories affect the way speakers of different languages evaluate objectively similar perceptual constructs.[4]

[3] The purpose of calculating CPI is to create a single, normalized index of similarity judgments across the three groups, and then correlate this index with the linguistic and sociocultural variables collected from bilingual participants. CPI was not calculated for near-colours as there were no significant differences between the groups for near-colour comparisons.

[4] A reviewer raises the concerns that Japanese and English speakers may be using the rating scale in a different fashion, that each individual's local and global color distances may differ (see, e.g., Indow, 1988), and that we have not taken into account individual categorical perception differences that depend on each person's colour perception differences and personal visual diet considerations. We share the reviewer's concern regarding the use of the rating scale and we believe this is an issue that cross-cultural studies should take into careful consideration. To minimize possible effects of differential use of the rating scale as a function of cultural background, participants in all three groups fell within the same age range, had similar socioeconomic backgrounds and had attained the same level of education. Furthermore, *z*-score transformations of each group's mean rating score was comparable for both within- and cross-category pairs, in both near- and far-colour comparisons. Specifically, for near-colour comparisons, the *z*-scores for English monolinguals, Japanese–English bilinguals and Japanese monolinguals were, respectively, .15, .01, −.24 (within-category), and .34, −.05, −.32 (cross-category). For far colour comparisons, the *z*-scores for English monolinguals, Japanese–English bilinguals and Japanese monolinguals were, respectively, .16, .07, −.36 (within-category), and −.08, .10, −.14 (cross-category). This means that participants' rating behaviour was reasonably consistent across groups, i.e., all groups used the rating scale in a similar fashion. With regard to individual differences in colour perception within each group, research has shown that despite huge individual differences in ocular media optical densities, people within the same culture describe physically identical stimuli similarly on many measures of colour appearance (Schefrin & Werner, 1990, 1993). Therefore, individual CP differences that depend on each

Our study also speaks to the issue of the relative impact of language and culture on human cognition. A challenge for linguistic relativity researchers is to explain the observed cognitive differences between populations. Any claim that these are driven by language may be challenged on the grounds that an extralinguistic factor may ultimately be causing speakers of different languages to behave differently. Usually this extralinguistic factor is defined in terms of some cultural variable. If one views language as part of one's cultural make-up, this may not be problematic. Under such a view, language is conceived as fundamentally a sociocultural phenomenon. Thus distinguishing between "linguistic" or "cultural" relativity is not important and the two terms may be used interchangeably to refer to the same phenomenon (see, e.g., Roberson et al., 2005). Even if we adopt the alternative view that language and culture are fundamentally distinct, one can still maintain that there is a concurrent influence of both on cognition. For example, according to Roberson (2005, personal communication), effects of language on cognition are ultimately culturally driven. Language is the mechanism that assists the influence of culture on cognition, acting as an intermediary between them. The role of language, in this scenario, is akin to that of an advertising board, highlighting, or reinforcing, aspects of reality that one's culture has taken a long-term interest in.

The study of bilingualism has provided fresh insights into the language vs. culture debate. Because cognitive patterns can be examined at various stages of development, it is possible to measure the relative impact of both linguistic and extralinguistic variables in "real time". While initial studies on grammatical number and object classification preferences showed that it may be both increasing proficiency in the L2 as well as length of stay in the L2-speaking country that may modulate the degree to which bilinguals shift their cognition towards the L2, subsequent studies provided a more nuanced picture by examining several linguistic and sociocultural variables on the observed cognitive shift. Thus Athanasopoulos (2007) and Athanasopoulos and Kasai (2008) found that in multiple regression/correlational analyses, it is ultimately increasing L2 proficiency that drives bilingual cognitive shift.

The study by Athanasopoulos (2009) on colour cognition provided an additional perspective to the emerging complex picture of the interaction between language, culture and bilingual cognition. The finding that semantic memory for the specific colour terms under investigation, as well as length of stay in the L2-speaking country, could independently predict cognitive shift strongly suggested that both language and culture may affect human cognition. The current paper adds to that investigation by considering the nature of bilingual cognitive shift in bilinguals with advanced L2 proficiency. We considered two possible scenarios: first, we speculated that individuals who have reached an advanced level of L2 proficiency may display fossilized cognition[5] (i.e., they may shift their cognitive disposition towards the L2 monolingual pattern permanently). If this turned out to be the case, then this would suggest that the nature of human cognition post-childhood is fixed and static. On the other hand, we also hypothesized that advanced bilinguals may still display cognitive flexibility, indicating that they can still "behave" in an L1-like way, depending on linguistic and/or sociocultural variables. Our results provide support for the latter hypothesis. We found that the degree to which advanced bilinguals resemble monolingual speakers of their L2 when they evaluate perceptual distinctions of colours depended on which language they used most frequently in their daily activities. Bilinguals who used predominantly English performed more similarly to English monolinguals, while bilinguals who used predominantly Japanese resembled more Japanese monolinguals. We found no effect of length of stay in the UK or of testing context.

These findings suggest that it is ultimately language that drives the observed cognitive effects. The pattern of bilingual behaviour reported in this study could be described as a language priming effect. Those bilinguals who use Japanese every day more frequently show a form of translation bias (even in English-speaking situations) that leads to a greater tendency to distinguish light blue (*mizuiro*) from blue (*ao*). The reverse holds for those bilinguals that use English more frequently. Exposure to the L2 culture is likely to be mediating this relationship, however, since living in the L2-speaking country and immersing oneself in its culture would potentially facilitate use of the L2.

While the results reported in this study point to some potentially interesting directions regarding the impact of bilingualism on the interaction of language and thought, there are several limitations that should be taken into consideration in future investigations. First, we have used a limited set of stimuli. This is largely because of the rigorous criteria we used for selecting the stimuli (within-group naming consistency of at least 80% in

person's colour perception differences would have a minimal effect on our results. Regarding personal visual diet considerations, research has shown that the categorizations of the Berinmo tribe inhabiting a dense rainforest environment (Roberson et al., 2000) are remarkably similar to the categorizations of the Himba tribe inhabiting a desert savannah environment (Roberson et al., 2004), thus differences in colour vision between populations or individuals are too subtle to affect the normal range of human performance (Davidoff, Goldstein & Roberson, 2009).

[5] Silvina Montrul is gratefully acknowledged for her insightful feedback on this possibility following a talk the first author gave at the Centre for Research on Bilingualism, Stockholm University in October 2008.

the Athanasopoulos et al., 2004, database). Even though we tested our whole set of stimuli twice, a computer-generated online task utilizing a visual search paradigm (as in Gilbert, Regier, Kay & Ivry, 2006; Roberson, Pak & Hanley, 2008) would have allowed us to use many more trials with the same stimuli. Second, the absence of the effect in the near-colour pairs in the present study is likely to be a verbalization artefact. Participants probably verbalized implicitly the stimuli they were exposed to and calibrated their ratings accordingly. Thus, manipulating perceptual distance in traditional offline similarity judgment tasks may not yield particularly informative results. Third, the precise timescale of online colour perception in different populations continues to remain elusive, and advances in electrophysiological techniques may provide a clearer picture in the future (see, e.g., Athanasopoulos, Wiggett, Dering, Kuipers & Thierry, 2009; Fontenaeu & Davidoff, 2007; Thierry, Athanasopoulos, Wiggett, Dering & Kuipers, 2009).

5. Conclusion

The present paper empirically investigated cognitive processing of colour in Japanese and English monolinguals, and in Japanese–English bilinguals. We found that Japanese monolinguals show categorical perception at the *ao*/*mizuiro* boundary whereas English speakers do not. The degree to which Japanese–English bilinguals resembled either monolingual norm depended on which of their two languages they use more frequently. By showing effects of language use on colour similarity judgments, the current study opens the way for further investigation, utilizing a range of experimental techniques including CP judgments and visual search, as well as a larger sample of participants that will in turn broaden the scope of the investigation and elucidate the precise nature of a possible link between language and thought in the bilingual mind.

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