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The automaticity of vantage point shifts within a synaesthetes' spatial calendar

Michelle Jarick*, Candice Jensen, Michael J. Dixon and Daniel Smilek

Department of Psychology, University of Waterloo, Ontario, Canada

Time–space synaesthetes report that time units (e.g., months, days, hours) occupy idiosyncratic spatial locations. For the synaesthete (L), the months of the year are projected out in external space in the shape of a 'scoreboard 7', where January to July extend across the top from left to right and August to December make up the vertical segment from top to bottom. Interestingly, L can change the mental vantage point (MVP) from where she views her month-space depending on whether she sees or hears the month name. We used a spatial cueing task to demonstrate that L's attention could be directed to locations within her time–space and change vantage points automatically – from trial to trial. We also sought to eliminate any influence of strategy on L's performance by shortening the interval between the cue and target onset to only 150 ms, and have the targets fall in synaesthetically cued locations on only 15% of trials. If L's performance was attributable to intentionally using the cue to predict target location, these manipulations should eliminate any cueing effects. In two separate experiments, we found that L still showed an attentional bias consistent with her synaesthesia. Thus, we attribute L's rapid and resilient cueing effects to the automaticity of her spatial forms.

Imagine for an instance, that every time you heard or saw a month of the year (e.g., April), you automatically experienced a rectangular spatial arrangement surrounding your midline, approximately a metre away, containing all of the months of the year, with each month occupying a very specific area of space. This seems completely normal to you and you are surprised when you find out that others do not experience months in this way. You learn that experiencing units of time (e.g., months, days, weeks, years) in specific spatial arrangements is known as time–space synaesthesia (see Sagiv, Simner, Collins, Butterworth, & Ward, 2006; Smilek, Callegas, Dixon & Merikle, 2007).

Now imagine that you prefer to view this *spatial calendar* from the vantage point of standing at June (i.e., June being directly in front of you), with April and May to your left and July and August to your right. As such, upon hearing your friend Lauren ask, 'Are you graduating in April?' your attention is immediately drawn to the area of space within the

*Correspondence should be addressed to Michelle Jarick, Department of Psychology, University of Waterloo, 200 University Avenue W., Waterloo, Ontario N2L 1C3, Canada (e-mail: majarick@uwaterloo.ca).

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spatial calendar where April is situated, for example 45° to your left. Then you run into Debra, who passes you a note asking the same question, 'Are you graduating in April?' but now, upon seeing the month April written (rather than spoken), the vantage point from which you initially viewed your spatial calendar while talking to Lauren suddenly changes. Essentially, it is as if you have jumped out of the rectangular calendar and are viewing it from the outside in, basically *reversing* your perspective of the spatial arrangement. From this new vantage point you are still standing at June, but April and May are now on your right and July and August now on your left. Consequently, you would now experience the written month of April as being located 45° to your *right*. This example illustrates an aspect of time–space synaesthesia experienced by some time–space synaesthetes, namely, that their time–space can be viewed from a variety of perspectives or mental vantage points (MVPs; Jarick, Dixon, Stewart, Maxwell, & Smilek, 2009). Here we explore these shifts in MVP in a synaesthete (L), whose MVPs appear to be determined by the modality (audition vs. vision) in which she encounters month names. Here we examine whether L's modality-dependent sifts in MVPs can occur automatically.

Time–space synaesthesia and the case of 'L'

Research is beginning to show that time–space synaesthesia might be more prevalent than previously thought. Recent evidence suggests that approximately 5–17% of the population associate time units (e.g., months of the year, days of the week, hours of the day, etc.) with very specific spatial locations (Sagiv *et al.*, 2006; Tang *et al.*, 2008; but see Brang, Teuscher, Ramachandran, & Coulson, 2010 who presented a conservative estimate of 2.2%). Notably, some individuals who associate time units with spatial locations have also been shown to possess spatial representations for other sequences as well, for example letters of the alphabet, digits, shoe sizes, television series, temperature, ages, etc. (Hubbard, Piazza, Pinel, & Dehaene, 2005; Hubbard, Ranzini, Piazza, & Dehaene, 2009). These *spatial forms* (Galton, 1880) are usually complex and idiosyncratic in nature and can be portrayed out in external space or in the minds' eye.

A proportion of synaesthetes who experience their months out in external space typically report being able to move around within their spatial representation, such that they can 'zoom in' or 'walk along' the months of the year (Cytowic & Eagleman, 2009; Galton, 1880; Sagiv *et al.*, 2006; Seron, Pesenti, Noël, Deloche, & Cornet, 1992). For example, if it is currently August 29, some synaesthetes will take the position of standing at August and will view the rest of the months relative to that position. Three weeks later, when the date changes to September 19, they will change perspective to be at September with all the other months of the year now relative to that month. Some researchers have noted that the ability of some synaesthetes to create and imagine a spatial calendar is due to a heightened visuo-spatial or memory ability (Brang *et al.*, 2010; Price, 2009). While this might be the case for associator synaesthetes whose spatial calendars are viewed within their minds' eye (Dixon, Smilek, & Merikle, 2004), projector synaesthetes who view their calendar out in external space and report navigating within and around the time–space representation could be beyond the scope of memory, and possibly even visuo-spatial ability. For instance, the synaesthete (L) that we study here, reported that the time units that make up her spatial calendar are experienced as though they were real objects out in the space around her, rather than as a mental representation in memory or simply a figment of her imagination. It is apparent, however, that there are substantial differences among synaesthetes with regard to their conscious experiences. The ability

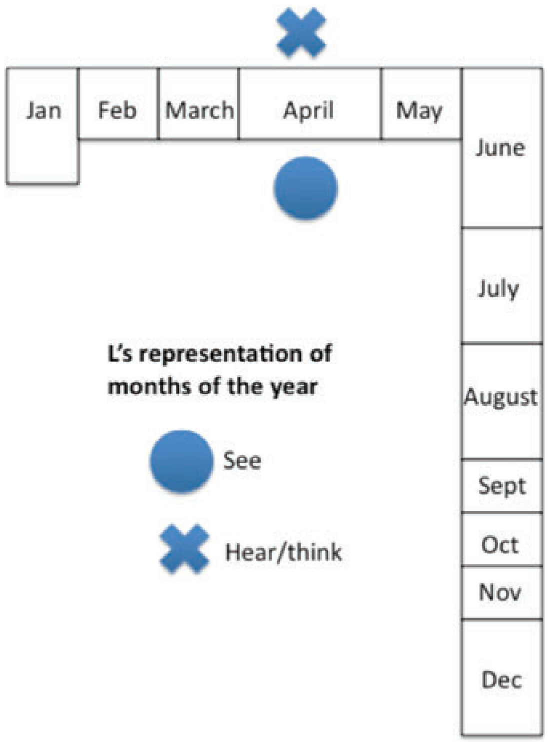

Figure 1. A bird's eye view drawing of the synaesthete L's spatial representation of the 12 months of the year. As illustrated, L represents her months in the shape of a 'scoreboard 7'. When L *hears* month names, she views 'late' months to her left and 'early' months to her right. Conversely, when L *sees* month names, she views 'early' months to her left and late months to her right.

to change MVP could be a critical element that highlights the qualitative difference between non-synaesthetes and synaesthetes (on the extreme end of the spatial-form continuum).

Although quite a few cases of time–space synaesthesia have been reported in the literature thus far (Mann, Korzenko, Carriere, & Dixon, 2009; Price & Mentzoni, 2008; Sagiv *et al.*, 2006; Smilek *et al.*, 2007), our time–space synaesthete (L) is able to navigate around her 'space' in a way that provides a unique opportunity for testing the automaticity of her MVP shifts. For L, the months of the year are projected out in external space in the shape of a 'scoreboard 7', where January to June extend across the top from left to right and July to December make up the vertical segment from top to bottom (see Figure 1 for a bird's eye schematic depiction of L's months[1]). However, what is imperative to this study is L's ability to change MVP to view her spatial calendar from different perspectives. L reports her 'default' position is at April, where she views the 7-shaped calendar upside down. From this perspective, January is to her right and extends to June on her left, with all of the months in view. Interestingly, this preferred vantage point is where L views her months when she *thinks about* or *hears* a month

[1] *We should mention that L views her spatial calendar surrounding her midline approximately 1 m away (just out of reach) such that the months July to December are sometimes out of view.*

name spoken aloud. When she visually *sees* a month name, however, her MVP completely reverses and the months now appear in the opposite locations in space. That is, from the visual perspective her 7-shaped calendar is now upright with January to her left extending to June on her right. This complete reversal of her MVP, depending on the way she encounters months (visually or aurally), allows us to easily study L's shifts in MVPs.

It is important to note here that L's modality-induced MVPs are extraordinary compared to any memory or visuo-spatial ability that one might have. Even those individuals with savant-like visuo-spatial and memory abilities would unlikely associate the modality of a stimulus with a specific mental perspective (unless perhaps the vantage point was cognitively useful).

Although time–space synaesthetes are showcased as an extraordinary group of individuals compared with the general population, to date the majority of research on spatial forms has shown that time–space synaesthetes generally share characteristics with other types of synaesthesia. From early informal inquiries (Cytowic, 2002; Galton, 1880; Seymour, 1980) to more recent descriptive evidence (Brang *et al.*, 2010; Eagleman (2009); Sagiv *et al.*, 2006) and empirical investigations (Mann *et al.*, 2009; Price & Mentzoni, 2008; Simner, Mayo, & Spiller, 2009; Smilek *et al.*, 2007), researchers have shown time–space associations to be (a) highly consistent, (b) involuntary or automatic, and (c) experienced since childhood.

Thus far in our examinations of L (Jarick *et al.*, 2009), she has demonstrated two of the three hallmark characteristics of synaesthesia: that her time–space mappings are highly consistent over test–retest sessions (compared to non-synaesthetic controls) and that she has had her time–space for as long as she can remember (i.e., since childhood). However, we have yet to show that L experiences her time–space involuntarily (or *automatically*). And more importantly, we have not yet shown that her MVPs are *automatically* determined by the modality of the inducer (i.e., visual or auditory).

Automaticity and spatial cuing

One way to assess the involuntary or automatic nature of time–space synaesthesia would be to evaluate the effect of time units on synaesthetes spatial attention. In the human attention literature, researchers often use four defining criteria to determine if a cue 'reflexively' (or in cognitive parlance, automatically) orients attention. The first factor is whether or not the cue orients attention despite being given explicit instructions to ignore the cue (Jonides, 1981). The second being whether the cue orients attention to a specific location even though the cue is counter-predictive (i.e., predicts the opposite location; Warner, Juola, & Koshino, 1990). The third is if the cue orients attention regardless of top-down strategic control (Kuhn & Kingstone, 2009; Warner *et al.*, 1990), and lastly, the fourth factor is if the cue orients attention rapidly (Jonides, 1981).

Although these characteristics have been classically associated with exogenous cues – such as an abrupt onset of a stimulus in the environment – more recent evidence suggests that they can be true also of endogenous cues (e.g., a schematic face looking left or right; Friesen & Kingstone, 1998; Kuhn & Kingstone, 2009). For instance, Friesen and Kingstone (1998) found that central cues such as a pair of eyes looking either left or right could reflexively orient our attention to the left or right, respectively. They classified the orienting effects of the gaze cues as reflexive shifts in attention based on some of the fundamental characteristics mentioned previously, such as the participants' attention was oriented to the cued locations despite the cue being non-predictive, and even at a short delay (105 ms) between the cue and target onset (i.e., cueing effects emerged rapidly).

Likewise, Smilek *et al.* (2007) relied on similar principles to demonstrate that time units (i.e., months of the year) could automatically orient the spatial attention of time–space synaesthetes. The researchers showed that centrally presented month cues whose synaesthetic month locations were on the left portion of the synaesthetes' spatial calendars rapidly oriented the synaesthetes' attention to the left side of space, thus allowing him/her to detect a target on the left side of a computer screen significantly faster than if the target was presented on the right side. The same cueing effects were found when the researchers cued the synaesthetes with months located on the right side of their spatial calendars (i.e., targets on the right were detected significantly faster than left targets). Satisfying the same two principles as Friesen and Kingstone (1998), Smilek *et al.* (2007) found reliable month cueing effects at a very short delay between cue and target onset – only 150 ms – and despite the cues being non-predictive of the target location. Based on these criteria, the authors concluded that month cues could *automatically* trigger shifts in spatial attention for some synaesthetes.

We recently used a similar method to validate L's MVP shifts (Jarick *et al.*, 2009). In this study, we demonstrated that L's attention could be successfully directed to the left or right when cued by central month names. Importantly, it objectively verified that L's attention could be directed in opposite directions depending on whether she was visually or aurally presented with the month cue. That is, given the months January, February, and March, L oriented her attention to the left when the cue was visual in the first session, but to the right when the month cue was presented aurally (i.e., spoken from loudspeakers) in the second session. Our findings replicated previous studies showing that month cues could direct time–space synaesthetes' spatial attention (Smilek *et al.*, 2007), while also extending those results to empirically validate that some time–space synaesthetes, such as L, could in fact change MVP from where they view their time–space. However, in this previous investigation we used a cue–target stimulus onset asynchrony (SOA) that was relatively long (600 ms) and the visual and auditory cues were presented in two separate sessions (i.e., blocked trials). Thus, our previous design did not allow us to conclusively determine whether the visual and auditory cues could trigger automatic shifts in her MVP.

The present studies

The present experiments sought to assess whether L's shifts in MVPs in her time–space were automatically elicited by the modality of the inducer (i.e., visual or auditory month cue). In two experiments, we use variants of the time–space cueing paradigm utilized in our previous studies (Jarick *et al.*, 2009; Smilek *et al.*, 2007). We evaluated the automaticity of L's modality-dependent MVPs by focusing on the previously described characteristics associated with reflexive orienting of attention. Specifically, we tested whether the auditory and visual month cues would differentially orient L's attention: (1) even when they were non-predictive of target location (equally valid and invalid), (2) when she was not able to predict in which modality the month names would be presented (and therefore which vantage point to take) on each trial, (3) even at very short cue-target intervals (i.e., 150 ms SOA), and (4) even when the cues are *counter*-predictive of the target location (i.e., 85% of the targets appeared in the 'wrong' locations).

To investigate the first two criteria, in Experiment 1 we used the same spatial cueing task we used previously with non-predictive cues (50% valid and 50% invalid; Jarick *et al.*, 2009). However, unlike our previous study, we amalgamated all the trials (visual and auditory) and presented them to L at random. That is, on any given trial, L could be cued by either a visual month name written on the computer screen, or an auditory month name spoken over the computer loudspeakers. Based on our previous findings in Jarick *et al.* (2009), we already confirmed that L's attention is influenced by month names even when the cues are non-predictive (satisfying the first characteristic of automatic orienting). What we do not yet know is whether the modality of month cue presentation can shift her MVP when the modality of cue presentation unpredictably changes from one trial to the next. If modality-dependent cueing effects are found with this randomized design, it would suggest that the modality of the month cue (whether visual or auditory) first triggers the MVP and then directs L's attention accordingly.

To more formally investigate the automaticity with which the modality of the month names could orient L's attention, and to rule out the possibility that L's modality-dependent cueing effects could be due to strategy use, Experiment 2 contained two critical manipulations to the spatial cueing task (addressing the last two criteria listed above). Like Smilek *et al.* (2007), we reduced one of the cue–target SOAs to only 150 ms (comparing it with a longer SOA of 800 ms). Secondly, we made the cues counter-predictive by loading up on synaesthetically invalid trials. In this design, only 15% of the trials were congruent (*valid*) with L's time–space. Therefore, if L can use a strategy to perform the task, then the optimal strategy for her to use would be to direct her attention to the *opposite* locations predicted by the month cues. Notably, she should only be able to use this strategy if given enough time (i.e., at the longer SOA of 800 ms). However, if the month cues rapidly shift L's attention in an *automatic* (i.e., reflexive) manner consistent with her MVPs, she should still demonstrate modality-dependent cueing effects at the 150 ms SOA despite the cues being counter-predictive. These findings would provide compelling evidence to suggest that month cues act as reflexive cues for L, and automatically orient her attention to locations within her time–space that are consistent with the cue-induced MVP.

EXPERIMENT 1

This experiment aimed to address whether L's modality-dependent cueing effects were truly elicited automatically by the modality of the inducer and free from strategic effects. To test this, we presented L with both visual and auditory cues randomly intermixed within the same testing session. In this situation, it would be very difficult (if not impossible) for L to use a strategy from one trial to the next that requires her to completely reverse her time–space associations. Alternatively, if her time–space associations are involuntarily activated by the modality of the inducer, she should still demonstrate modality-dependent cueing effects consistent with Jarick *et al.* (2009).

Method

Participants

A 21-year-old female with time–space synaesthesia (L) and 15 naïve non-synaesthetic controls (eight males, $M = 23$ years old) volunteered to participate for course credit. The controls were fully debriefed at study completion regarding the characteristics and forms of synaesthesia and were asked if they have ever experienced any similar spatial associations. None of the participants reported any form of time–space representation and were intrigued by the phenomenon. When the synaesthete (L) initially reported her vivid time–space associations, she was tested for consistency using the same method as Smilek *et al.* (2007), and showed very high consistency over test–retest sessions (see Jarick *et al.*, 2009 for more details). All participants had normal or corrected-to-normal vision and hearing, were right handed, and reported no reading or language difficulties. The University of Waterloo Office of Research Ethics approved all procedures and participants gave written consent before participating.

Materials

We used the same spatial cueing task that was used previously to validate L's MVP shifts (Jarick *et al.*, 2009). All stimuli were presented on a 17-in. LCD flatscreen computer monitor in black on a white background. The fixation cross subtended 0.6° of visual angle in all directions. There were six different month cues: three early months (*January*, *February*, *March*) and three later months (*May*, *June*, *July*). The visual month cues were written in black text (Geneva font, 72 pt. created in SuperLab 4.0), measuring 0.7° in height and maximally 6.5° in length – *February*). Targets were black squares (each side 0.6°) presented to the left or right of the cue. The targets were placed 10.5° in eccentricity from the center of fixation. The auditory month cues were the same month names broadcast in stereo over the computer speakers located on each side of the computer monitor facing the participant. A button box was located on the table in front of the participant to collect the participants' responses. SuperLab 4.0 experimental software (Cedrus Corporation, 2011) was used to display the stimuli and to collect the response times.

Procedure

Participants were seated unrestrained at a distance of 57 cm in front of the computer monitor. They were asked to press a centrally located key on a button box as quickly and accurately as possible with their right (dominant) hand once they detected the presence of the target. In the case where the target was absent (i.e., 'catch' trials), they were instructed to withhold their response and wait for the next trail. Participants were advised that the month cues did not predict the target location and to focus on detecting the targets as quickly as possible without making errors (responding on catch trials). The events in a trial were as follows: a fixation cross for 680 ms, replaced randomly by either a visual or aural month cue (e.g., *January*, *February*, *March*, *May*, *June*, or *July*) for 600 ms, followed by a target square presented to the left or right of the cue for 3,500 ms or until the participant responded. The month cues were not statistically predictive of the target locations, since on half (50%) of the trials the target was presented on the side of the display synaesthetically cued by the month name (valid trials), whereas on the other half (50%) of the trials the targets were presented on the opposite side (invalid trials). Participants performed two sessions with a 5-min break in between. For L, each session contained four blocks of 132 randomized trials (60 valid, 60 invalid, and 12 catch trials). To minimize boredom for controls we removed a block of trials, such that each session contained three blocks of 132 trials each (60 valid, 60 invalid, and 12 catch). Visual and auditory month cues were randomly intermixed within each testing session. All participants were given 20 practice trials (8 valid, 8 invalid, 4 catch) to acquaint them with the task. The 'catch' trials contained no target and were inserted to make sure that the participants were paying attention to the task, as well as to discourage participants from making anticipatory responses. Sessions lasted about 20 min each, amounting to approximately 45 min of testing in total.

Results and Discussion

L performed perfectly on auditory and visual 'catch' trials (100%). Control participants with less than 80% accuracy on either auditory or visual 'catch' trials were excluded from subsequent analysis. Two participants were excluded based on this criterion. The mean accuracy on catch trials for the remaining control participants was 97.6% on auditory trials and 97.3% on visual trials. Participants' response times (RTs) were submitted to recursive outlier analyses using the sample size dependent rejection cut-off (± 2.5 *SD*) put forth by Van Selst and Jolicoeur (1994). Two participants had more than 20% of their observations removed during this procedure, and as a result, were not included in any statistical analyses. As for the remaining participants, 3.75% of L's observations and 8.74% (on average) of control's observations were discarded using this outlier rejection procedure.

The remaining RTs were submitted to a two-way analysis of variance (ANOVA), with inducer (auditory or visual month cue) and validity (valid or invalid target location) as factors. We performed separate ANOVAs on L's data and the data from the group of control participants. Validity, in this case, refers to L's expected behaviour on this cueing task. Specifically, we predicted that L would be faster at detecting targets if they appeared on the same (valid) side of space as her synaesthetic location for the month cue and slower at detecting targets if they appear on the opposite (or invalid) side of space as her synaesthetic location for the moth cue. For instance, given an auditory month cue, we expect L will be faster at detecting right (valid) targets if they are preceded by early months (*January*, *February*, *or March*) and faster at detecting left (valid) targets if they are preceded by late months (*May*, *June*, *or July*). Conversely, for visually presented month cues, L should reverse her MVP (refer to Figure 1) and the opposite predictions apply. That is, following a visual month cue, we predict L will be faster to detect right (valid) targets when preceded by late months and faster to detect left (valid) targets when preceded by early months. For the non-synaesthetic controls, targets should not have 'valid' or 'invalid' locations as the month cues should not influence the direction of their spatial attention[2].

A Bonferroni correction (alpha of $.05/2 = .025$) was used to interpret the results of L's and the group of controls ANOVAs. The two-way ANOVA on the group of control participants revealed no significant main effects or a significant inducer by validity interaction (all F's $< .75$, all p's $> .39$). As predicted, however, L showed a significant main effect of validity, $F(1, 458) = 244.95$, $p < .001$, detecting targets located in 'valid' locations faster than targets located in 'invalid' locations (Figure 2). L also showed a main effect of inducer, $F(1, 458) = 31.74$, $p < .001$, whereby she detected targets significantly faster if they were preceded by visual month cues than if they were preceded by auditory month cues. The two-way interaction between inducer (auditory or visual) and validity

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[2] *Some research suggests that non-synaesthetic controls may hold an implicit left-to-right representation for the months of the year (Gevers, Reynvoet, & Fias, 2003; Price, 2009). We tested this possibility but failed to find evidence that any of our non-synaesthetic controls hold an implicit left-to-right representation for the months of the year (all F's < 7.9, all p's $> .006$, the Bonferroni corrected values for multiple ANOVAs for each individual control).*

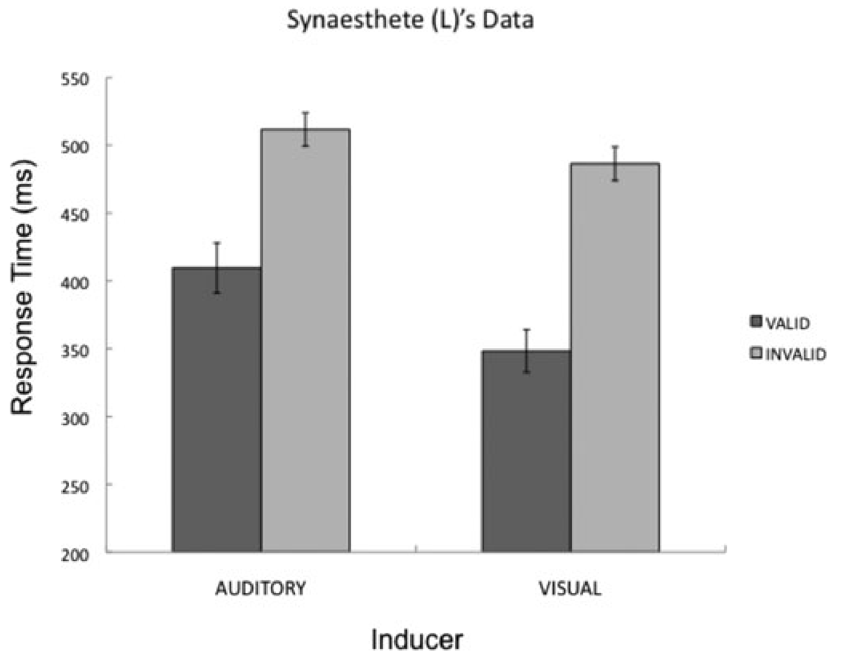

Figure 2. L's mean response times to detect targets in 'valid' and 'invalid' spatial locations following the presentation of auditory and visual month cues. The error bars represent the 95% confidence intervals.

(valid or invalid location) was also significant for L, $F(1, 458) = 5.54$, $p = .019$. The source of the two-way interaction is apparent in Figure 2, where the cueing effects seem to be stronger following auditory cues than visual cues (RT difference between valid trials was 61.28 ms, $p < .001$). This makes sense considering that L prefers viewing her months from the auditory MVP.

To directly compare the magnitude of L's cueing effects to the cueing effects observed by the control group, we performed planned comparisons using Crawford and Garthwaite's (2005) Revised Standardized Difference Test (RSDT). This test was specifically designed to assess whether the difference between two observations (valid vs. invalid) is significantly larger for one case (L) compared to a small control sample. We performed these tests for both auditory and visual month cues, comparing L to the control group of non-synaesthetes. A Bonferroni correction (alpha of $0.05/2 = .025$) was applied to control for multiple tests. The planned comparisons revealed that L showed significantly larger cueing effects than controls following both auditory month cues RSDT $t(14) = 5.53$, $p < .0001$ and visual month cues, RSDT $t(14) = 5.12$, $p < .0001$.

L's slower RTs following invalid trials and faster RTs following valid trials is indicative of a spatial cueing effect – an effect observed here for L, but not for controls. Table 1 shows the mean RTs for each participant on valid and invalid trials, and the magnitude of each participant's cueing effects (invalid minus valid RTs) following both auditory and visual cues. As highlighted in Table 2, L shows considerably larger cueing effects following both auditory and visual cues, than any of the cueing effects observed for non-synaesthetic controls.

To test whether L's cueing effects are in fact larger than those observed by her most comparable control (participant C7), we submitted L and C7's RTs to two ANOVAs

Table 1. Experiment 1: Mean response times (RTs) and standard deviations (*SD*s) in ms for the synaesthete L and each of the 15 controls (C) for visual and auditory month cues

Inducer	Auditory					Visual				
	Valid		Invalid		Cueing effect	Valid		Invalid		Cueing effect
	RT	(*SD*)	RT	(*SD*)	RT (In*V* − *V*)	RT	(*SD*)	RT	(*SD*)	RT (In*V* − *V*)
L	410	(102)	512	(87)	*102*	348	(67)	486	(68)	*138*
C1	256	(32)	251	(31)	*−5*	278	(38)	284	(54)	*5*
C2	446	(111)	443	(119)	*−3*	449	(121)	444	(114)	*−5*
C3	287	(39)	281	(42)	*−6*	284	(38)	290	(37)	*6*
C4	467	(160)	430	(125)	*−37*	521	(189)	461	(132)	*−60*
C5	274	(33)	267	(31)	*−7*	283	(32)	292	(34)	*9*
C6	356	(75)	332	(60)	*−24*	405	(89)	442	(133)	*37*
C7	405	(143)	447	(188)	*42*	355	(93)	386	(105)	*31*
C8	279	(29)	271	(27)	*−8*	276	(32)	272	(32)	*−4*
C9	402	(80)	378	(66)	*−24*	388	(78)	419	(88)	*31*
C10	344	(36)	346	(43)	*2*	389	(68)	386	(51)	*−3*
C11	298	(34)	290	(22)	*−8*	297	(26)	296	(34)	*−1*
C12	284	(28)	284	(31)	*0*	297	(35)	288	(27)	*−9*
C13	323	(46)	323	(49)	*0*	306	(48)	319	(59)	*13*
C14	298	(32)	301	(38)	*3*	318	(44)	345	(74)	*27*
C15	274	(40)	277	(42)	*3*	307	(54)	298	(57)	*−9*
AVG	333	(61)	328	(61)	*−5*	344	(66)	348	(69)	*5*

Note. The cueing effects are shown in italics and represent the difference between invalid and valid trials (invalid − valid). Validity in this context refers to whether targets appeared in a spatial location either consistent (valid) or inconsistent (invalid) with L's synaesthetic representations. The averages are of the controls only and do not include L.

(containing aural trials and visual trials, separately), both with participant ID (L or C7) and validity (valid or invalid target locations) as factors. The logic behind this analysis is as follows: if L's cueing effects (measurable by cue validity) are in fact significantly larger than C7's, then both ANOVAs should reveal significant participant ID (L or C7) by validity (valid or invalid) interactions. To control for multiple tests, a Bonferroni correction (alpha of $.05/2 = .025$) was used interpret the results of the ANOVAs.

As expected, the ANOVA for aural trials revealed a significant ID (L or C7) by validity (valid or invalid) interaction, $F(1, 388) = 5.11$, $p = .024$, confirming that L's cueing effects on aural trials were in fact larger than C7's. This ANOVA also revealed a main effect of validity, $F\,(1, 388) = 29.41$, $p < .001$, with valid trials being responded to faster (on average) than invalid trials, and a main effect of participant ID, $F(1, 388) = 6.79$, $p = .01$, with C7 responding faster (on average) than L. Subsequent simple effect analyses (interpreted using a Bonferroni correction, alpha of $.05/2 = .025$) revealed that the source of the interaction was the presence of a significant main effect of validity for L, $F(1, 233) = 68.04$, $p < .001$, but not for C7, $F(1, 155) = 2.47$, $p = .118$.

The ANOVA for visual trials revealed similar results. Specifically, the participant ID by validity interaction, $F(1, 379) = 39.60$, $p < .001$, the main effect of validity, $F(1, 379) = 98.50$, $p < .001$, and the main effect of participant ID, $F(1, 379) = 29.76$, $p < .001$ were all significant. Subsequent simple effect analyses (interpreted using a

Bonferroni correction, alpha of .05/2 = .025) revealed that, as with aural trials, the source of the interaction was the presence of a significant main effect of validity for L, $F(1, 225) = 239.13, p < .001$, but not for C7, $F(1, 154) = 3.77, p = .054$.

The combined results converge to show that L was indeed responding according to her time–space associations even though the cues were not predictive of the target location. It is interesting to note in Table 1 that L's RTs for valid trials were within the range of the controls RTs, however her RTs for invalid trials were slightly longer. This effect has been seen frequently throughout the synaesthesia literature (see Jarick *et al.*, 2009 for a discussion) and typically represents a cautious response strategy taken by the synaesthete. While this could be the case here for L, the fact that her RTs were in the range of controls for valid trials implies that she was not being cautious during those trials. Alternatively, we believe the increase in RTs for invalid trials is most likely due to L having to re-direct her attention from the locations cued by the month names to the location on the other side of space where the target appeared on these invalid trials. Thus, although the cues were not predictive of target location, they still influenced L's attention to the synaesthetically valid locations for at least the majority of the trials.

Most importantly, L was responding in accordance with her visual and auditory MVPs. Seeing as though the visual and auditory cues were randomly presented within one session, these findings suggest that L's MVPs are elicited rapidly (from one trial to the next), if not *automatically* considering that there was no reason for L to even pay attention to the month cues as they were not predictive of target location. Thus, our results satisfy at least one of the characteristics of a reflexive cue for L, mainly that month names oriented L's attention despite being irrelevant to the task (Jonides, 1981). Moreover, the presence of L's modality-dependent cueing effects strongly argues against a strategy explanation; in our previous study where auditory and visual cues were blocked it might have been possible for L to adopt a strategic set – always viewing her spatial calendar from the auditory MVP and then the visual MVP. In the current study since auditory and visual trials were intermixed, it would have been virtually impossible for L to implement the appropriate strategy without knowing which MVP to take before each trial.

EXPERIMENT 2

The results of Experiment 1 provide the initial evidence to support the conclusion that the months *automatically* cue the appropriate MVP dictated by the modality of the inducer. Even though it is highly unlikely that L could have used a strategy in Experiment 1, we still lack the necessary evidence to confidently support the automaticity of her spatial forms due to the use of a long cue–target SOA (600 ms). Hence, to further assess whether L's cueing effects were due to strategy or automaticity, we modified the cueing task in two ways: (1) we included trials with a short cue–target SOA of only 150 ms (too quick to use a strategy), and (2) made the cues *counter*-predictive by loading up on invalid trials (85%). Consequently, if L were to use a strategy to perform well in this task, she would need to use a strategy that is in direct contrast to her synaesthetic time–space representation for each MVP (auditory and visual trials were blocked in this case). In order for L to do this, she would need to re-orient her attention to the opposite side of space from where the month cued her – which would likely take time. Thus, we predict that if L is able to use this strategy, she will only be able to do so at the longer SOA of 800 ms; at the short SOA of 150 ms, L will either show cueing effects consistent with her synaesthesia or diminish any cueing effects that were found previously in Experiment 1.

Table 2. Experiment 2 (auditory month cues): Mean response times (RTs) and standard deviations (*SD*s) in ms for the synaesthete L and each of the 15 controls (C) for trials with short SOAs (150 ms) and trials with long SOAs (800 ms)

SOA	150					800				
	Valid		Invalid		Cueing effect	Valid		Invalid		Cueing effect
	RT	(*SD*)	RT	(*SD*)	RT(In*V* − *V*)	RT	(*SD*)	RT	(*SD*)	RT(In*V* − *V*)
L	465	(44)	487	(62)	*22*	311	(41)	325	(38)	*14*
C1	286	(78)	286	(58)	*0*	266	(63)	261	(74)	*−5*
C2	353	(30)	329	(28)	*−24*	287	(38)	283	(37)	*−4*
C3	333	(47)	328	(43)	*−5*	271	(31)	268	(38)	*−3*
C4	310	(67)	308	(53)	*−2*	286	(52)	286	(48)	*0*
C5	332	(100)	348	(51)	*16*	280	(60)	289	(84)	*9*
C6	347	(39)	344	(51)	*−3*	310	(65)	305	(87)	*−5*
C7	270	(38)	283	(38)	*13*	260	(37)	256	(44)	*−4*
C8	303	(54)	313	(57)	*10*	281	(64)	266	(51)	*−15*
C9	353	(22)	337	(27)	*−16*	304	(30)	290	(39)	*−14*
C10	316	(43)	319	(40)	*3*	287	(51)	285	(66)	*−2*
C11	327	(44)	338	(37)	*11*	327	(73)	323	(69)	*−4*
C12	285	(31)	286	(34)	*1*	268	(49)	268	(41)	*0*
C13	334	(31)	344	(28)	*10*	272	(35)	276	(32)	*4*
C14	272	(49)	271	(47)	*−1*	270	(47)	259	(59)	*−11*
C15	288	(36)	282	(37)	*−6*	254	(52)	255	(43)	*1*
AVG	314	(47)	314	(42)	*0*	282	(50)	278	(54)	*−4*

Note. The cueing effects are shown in italics and represent the difference between invalid and valid trials (invalid − valid). Validity in this context refers to whether targets appeared in a spatial location either consistent (valid) or inconsistent (invalid) with L's synaesthetic representations. The averages are of the controls only and do not include L.

Method

Participants

The time–space synaesthete (L) and 16 naïve non-synaesthetic controls (five males, $M =$ 22.3 years old) volunteered to participate in this study for course credit. None of the participants reported any form of time–space associations. All participants had normal or corrected-to-normal vision and hearing, were right handed, and reported no reading or language difficulties. The University of Waterloo Office of Research Ethics approved all procedures and participants gave written consent before participating.

Materials

All stimuli and equipment were the same as Experiment 1.

Procedure

We modified the procedure slightly from Experiment 1. The two sessions were once again split between visual and auditory cues, with the visual session always performed first and the auditory session second (to keep the order consistent with L). The blocking of month cues into visual and auditory sessions was done to avoid unnecessarily complex analyses [four-way interactions]. Instead of having only one cue–target SOA as in Experiment 1 (i.e., 600 ms), we intermixed trials with two different SOAs: a long SOA of 800 ms and a very short SOA of 150 ms. The sessions no longer contained equal amounts of valid and invalid trials, they now contained 85% invalid and only 15% valid trials, randomly presented. In this experiment, the month cues were predictive of the target location on 85% of the trials, but being in contrast to L's time–space (i.e., predicting the opposite location) actually made them counter-predictive *for L*. Unlike Experiment 1, participants were not explicitly informed of the cue–target probability in this experiment. They were only advised to detect the target as quickly as possible. Participants completed 360 trials per session (visual and auditory), with 72 trials valid and 288 invalid. Among valid and invalid trials, we also inserted 72 (15%) catch trials to ensure that participants were performing the task. Each session lasted about 20 min each, amounting to about 45 min of testing in total.

Results and Discussion

L's performance on both auditory and visual 'catch' trials was perfect (100%). Participants' mean accuracy on catch trials was 99.3% in the auditory cue condition and 97.5% in the visual cue condition. No participants were excluded based on their performance on catch trials – as all participants had greater than 80% accuracy on these trials. As in Experiment 1, participants RTs were submitted to a recursive outlier analysis using the sample size dependent rejection cut-offs proposed by Van Selst and Jolicoeur (1994). As a result, RTs that were greater than ± 2.5 standard deviations were removed from invalid trials ($N = 144$) and RTs that were greater than ± 2.44 were removed from valid trials ($N = 36$). Data from one participant (auditory cue condition) were discarded, as approximately 28% of their observations on invalid trials were removed during this procedure. For L, this procedure resulted in the removal of 2.4% of observations on invalid trials and 1.4% of observations on valid trials in the auditory cue condition, and 4.2% of observations on invalid trials and 6.94% of observations on valid trials in the visual cue condition. For controls in the auditory cue condition, an average of 9.1% of observations was removed from invalid trials and 6.9% of observations from valid trials. For controls in the visual cue condition, an average of 6.5% of observations was removed from invalid trials and 4.9% from invalid trials.

The remaining RTs for each cue modality (visual and auditory) were submitted to separate two-way ANOVAs – one for L and one for the average group of controls. Each ANOVA involved both SOA (150 or 800 ms) and validity (valid or invalid target) as factors. Again, validity in this context refers to whether or not targets appeared in locations that were consistent or inconsistent with L's synaesthetically experienced spatial locations for the various month cues (refer to Figure 1). Thus, for aurally presented month cues, valid trials were those where right targets were preceded by early month cues or where left targets were preceded by late month cues. However, for visually presented month cues, L's month-space associations are reversed. Thus, valid trials were those where left targets were preceded by early month cues or where right targets were preceded by late month cues. To control for type-I error rates, a Bonferroni correction was used to interpret the results obtained from the four ANOVAs (alpha of $.05/4 = .0125$).

In both ANOVAs, we predicted that L would show a main effect of validity by responding faster to targets appearing in 'valid' locations than to targets appearing in

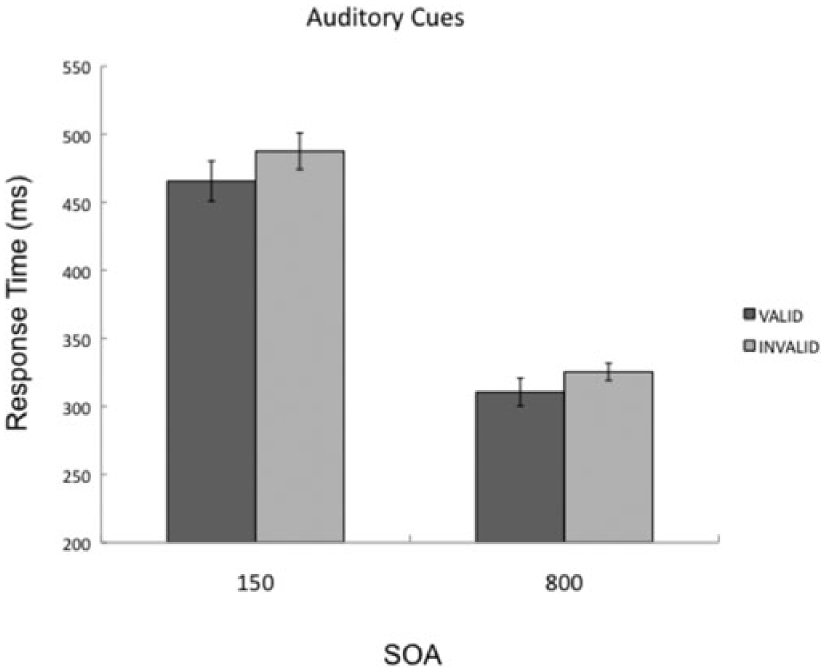

Figure 3. L's mean response times to detect targets in 'valid' and 'invalid' locations when the delay between *auditory* month cues and targets is short (150-ms SOA) and when the delay between *auditory* month cues and targets is long (800-ms SOA). The error bars represent the 95% confidence intervals.

'invalid' locations. Moreover, as we assert that it is the automatic orienting of L's attention to the synaesthetic locations occupied by her months that facilitates (or impedes) her target detection in this cueing paradigm, (not the use of strategy), we specifically predict that L would show cueing effects at the 150 ms SOA, but not necessarily at the 800 ms SOA, (as 800 ms is long enough to implement a strategy).

With regards to the ANOVA for aurally presented month cues, L showed a main effect of SOA [$F(1, 348) = 576.46$, $p < .001$], reflecting her faster detection of targets when the delay between the cue and the target was long (800-ms SOA) rather than short (150-ms SOA). As predicted, L also showed a main effect of validity, [$F(1, 348) = 7.75$, $p = .006$], detecting targets faster if they appeared in 'valid' spatial locations than if the targets appeared in 'invalid' spatial locations (Figure 3). L did not show a significant SOA by validity interaction, [$F(1, 348) = .302$, $p = .583$], indicating that the main effect of validity was not modulated by the delay between the cue and target onset. The ANOVA for the group of controls revealed only a significant main effect of SOA [$F(1, 56) = 30.97$, $p < .001$], reflecting participants' faster detection of targets when the delay between the cue and the target was long (800-ms SOA) than when the delay between the cue and the target was short (150-ms SOA). Neither the main effect of validity, nor the validity by SOA interaction were significant (both F's $< .381$, both p-values $> .75$).

The ANOVA for visually presented month cues revealed a main effect of validity for L, [$F(1, 339) = 43.23$, $p < .001$], showing that detecting targets was faster if they appeared in 'valid' spatial locations than if they appeared in 'invalid' spatial locations (Figure 4).

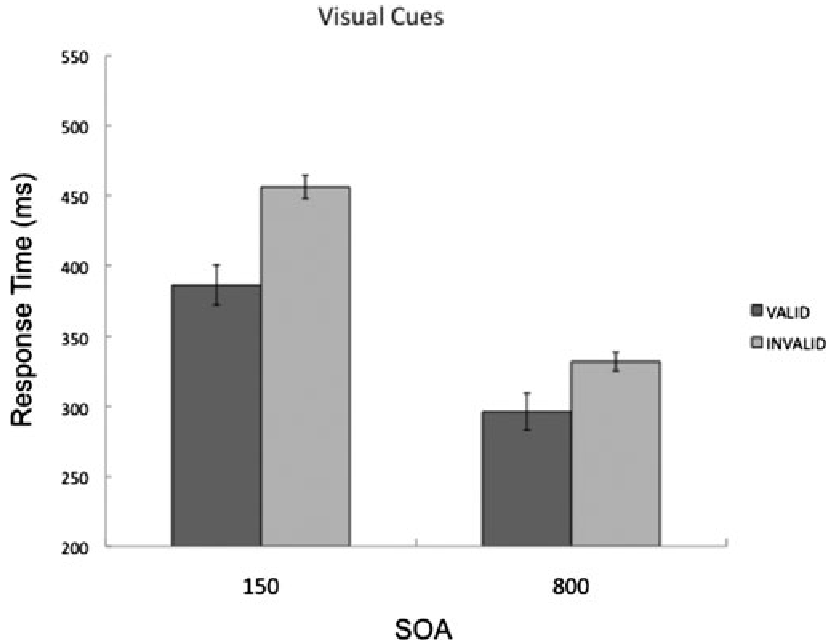

Figure 4. L's mean response times to detect targets in 'valid' and 'invalid' locations when the delay between *visual* month cues and targets is short (150-ms SOA) and when the delay between *visual* month cues and targets is long (800-ms SOA). The error bars represent the 95% confidence intervals.

L also showed a main effect of SOA, [$F(1, 339) = 177.12$, $p < .001$], reflecting faster detection of targets at long SOA (800 ms) than short SOA (150 ms). The ANOVA for the controls revealed neither significant main effects nor a significant two-way interaction (all F's $< .104$, all p-values $> .540$).

As in Experiment 1, only L's RTs were faster following valid trials than invalid trials for both MVPs – indicative of modality-dependent cueing effects for L – but not for controls. Note that L showed these cueing effects, notwithstanding the fact that targets appeared in invalid locations on approximately 85% of the trials. As the best strategy for L to adopt in this task is to go *against* her synaesthetic month-space associations, her significant cueing effects suggest that month cues automatically guided her attention to her synaesthetic spatial locations for the respective months, preparing her to respond faster to subsequent validly located target locations. Moreover, the SOA between cue and target did not significantly modulate L's cueing effect in either the auditory or the visual cue conditions, suggesting that L's cueing effects were unlikely reflective of the use of some sort of strategy.

Table 2 shows the mean RTs for each participant on valid and invalid trials in the auditory cue condition, and also the magnitude of each participant's cueing effects (invalid minus valid) on trials with short and long SOAs. As this table highlights, L shows significantly larger cueing effects than controls at either SOA. Table 3 shows the means and cueing effects for each participant for visually presented month cues. Similar to the aurally presented cues, L shows much larger cueing effects at both short and long SOAs than any of the non-synaesthetic controls. To directly compare L's cueing effects at both short and long SOAs to the group of controls, we performed separate planned comparisons for the short and long SOAs, from both the auditory cue and visual cue

Table 3. Experiment 2 (visual month cues): Mean response times (RTs) and standard deviations (*SDs*) in ms for the synaesthete L and each of the 16 controls (C) for trials with short SOAs (150 ms) and trials with long SOAs (800 ms)

SOA	150					800				
	Valid		Invalid		Cueing effect	Valid		Invalid		Cueing effect
	RT	(*SD*)	RT	(*SD*)	RT(In*V* − *V*)	RT	(*SD*)	RT	(*SD*)	RT(In*V* − *V*)
L	386	(42)	456	(80)	*70*	296	(24)	332	(39)	*36*
C1	406	(78)	386	(58)	*−20*	361	(74)	374	(63)	*13*
C2	333	(31)	336	(28)	*3*	350	(38)	337	(37)	*−13*
C3	365	(47)	371	(43)	*6*	340	(31)	349	(38)	*9*
C4	371	(67)	338	(53)	*−33*	329	(48)	318	(53)	*−11*
C5	426	(100)	380	(51)	*−46*	370	(60)	381	(84)	*11*
C6	369	(39)	385	(51)	*16*	355	(65)	379	(87)	*24*
C7	356	(38)	345	(38)	*−11*	347	(37)	336	(44)	*−11*
C8	379	(54)	379	(57)	*0*	363	(64)	371	(51)	*8*
C9	315	(22)	312	(27)	*−3*	337	(30)	346	(39)	*9*
C10	312	(43)	315	(40)	*3*	344	(51)	363	(66)	*19*
C11	313	(31)	320	(34)	*7*	320	(49)	345	(41)	*25*
C12	364	(31)	366	(28)	*2*	371	(35)	382	(32)	*11*
C13	325	(49)	329	(47)	*4*	358	(47)	347	(59)	*−11*
C14	314	(36)	302	(37)	*−12*	291	(52)	282	(43)	*−9*
C15	327	(32)	334	(31)	*7*	318	(32)	315	(50)	*−3*
C16	335	(44)	332	(37)	*−3*	339	(73)	328	(67)	*−11*
AVG	351	(46)	346	(41)	*−5*	343	(49)	347	(53)	*4*

Note. The cueing effects are shown in italics and represent the difference between invalid and valid trials (invalid – valid). Validity in this context refers to whether targets appeared in a spatial location either consistent (valid) or inconsistent (invalid) with L's synaesthetic representations. The averages are of the controls only and do not include L.

conditions using the RDST procedure developed by Crawford and Garthwaite (2005). A Bonferroni correction (of alpha $0.05/4 = .0125$) was applied to control for multiple tests. The planned comparisons for the auditory month cue condition, revealed that L showed a significantly larger cueing effect than controls for trials with both long and short SOAs, $t(14) = 2.80$, $p < .01$ and $t(14) = 2.71$, $p = .01$, respectively (one tailed). The planned comparisons for visual month cue condition also revealed that L showed significantly larger cueing effects on both trials containing short and long SOAs, $t(15) = 5.21$, $p = .0001$ and $t(15) = 3.13$, $p = .005$, respectively (one tailed).

The result that the month cues rapidly directed L's spatial attention to locations consistent with her synaesthetic time–space (within 150 ms) for each of the MVPs provides further evidence that her MVPs are elicited automatically, and satisfies yet another criteria for months reflexively cueing L's attention (i.e., that attention is oriented rapidly – Jonides, 1981). Moreover, L also showed modality-dependent cueing effects consistent with both MVPs at the 800-ms SOA, suggesting one of two possibilities – that she was either not trying to use the opposing strategy predicted by the cues, or *could not* use the strategy because it contrasted with her time–space. We favour the latter possibility that L was trying to adopt the opposing strategy, but was unsuccessful at doing so. This is implied by the overall longer RTs for L compared to the group of controls which could be taken as L's attempt to employ a strategy. However, since her validity effects were in the direction cued by her synaesthesia, it is clear that she was unable to implement the strategy successfully. We take these findings as evidence that L's modality-dependent cueing effects observed in these experiments were not due to strategy, but rather due to the involuntary and automatic influence of L's spatial calendar. This experiment alone satisfied two more defining characteristics suggesting that month cues reflexively orient L's attention in a manner consistent with both her visual and auditory MVPs, by showing that L produced modality-dependent cueing effects within 150 ms (consistent with Smilek *et al.*, 2007) and despite the cues being counter-predictive of the target location.

GENERAL DISCUSSION

The current study was the first to explore the automaticity with which month names triggered shifts in MVP within a time–space synaesthetes' spatial calendar. We specifically focused on the synaesthete L, who we had previously confirmed could change MVP depending on if she was induced visually or aurally with the month name. In the present study, we extended our previous findings and verified that L could switch MVP very quickly, from one trial to the next (Experiment 1) and within 150 ms (Experiment 2). There had previously been contentions in the literature that synaesthetes might perform according to a demand characteristic induced strategy (Gheri, Chopping, & Morgan, 2008), or by having superior mental imagery ability (Price, 2009), however our findings from both experiments suggest that these possibilities are highly unlikely, if not impossible. In Experiment 1, it would have been nearly impossible for L to switch MVP from trial to trial – taking one MVP for visual trials and the opposite for auditory – especially considering that the month cues were presented in random order. In this design, there was no opportunity for L to prepare two opposing mental images given the unpredictability of the cue type. Furthermore, Experiment 2 demonstrated modality-dependent cueing effects consistent with both MVPs with only 150 ms between cue and target onset, which is widely known as being too short a time to formulate and initiate a strategy. Yet, even if we entertained the idea that she could have employed a strategy, then the optimal strategy would have been for her to re-direct attention in the opposite spatial locations relative to her synaesthetic MVP (of which L was still not capable). Therefore, we interpret our results as strong confirmation that L is a time–space synaesthete who is able to move around her spatial calendar and rapidly take on different MVPs. Most importantly, not only do month cues act like reflexive cues for L, automatically triggering shift in her visual attention within her month-space, L's MVPs are automatically elicited by the modality of the month cue, (taking one MVP when the cue is visual and the opposite MVP when the cue is auditory).

The idea surrounding the ability of some synaesthetes to navigate within their spatial forms and view their space from different MVPs could provide important clues regarding the cognitive architecture and neurological processes that underlie this form of synaesthesia, or more generally synaesthesia as a whole. As Eagleman (2009) pointed out, this ability to navigate within spatial forms might indicate that spatial forms comprise an internal coordinate system that is not solely defined relative to the synaesthetes' body, but rather a coordinate system relative to the other concepts (or 'objects') within the representation. That is, although the months may not always contain fixed coordinates relative to the synaesthetes' body, they most likely always have fixed positions relative to other months (or objects) within the spatial representation. This is why one of the defining attributes of synaesthesia is the synaesthetes' consistency in reporting their experience. It could be that cortical regions responsible for processing spatial coordinates or frames of reference (i.e., posterior or inferior parietal regions; Hubbard *et al.*, 2005) are involved in experiencing synaesthetic spatial forms. The research presented in this paper supports the possibility of a specialized neural mechanism underlying time–space synaesthesia that can operate and rapidly independently of top-down control.

Another intriguing characteristic of L is that she has preferred MVPs (auditory and visual perspectives) to view her months, where her default standpoint is in front of April. More specifically, L reports that the auditory MVP is the outlook she typically takes to view her spatial calendar. From conversations with L, our theory for why she developed these opposing modality-dependent MVPs is that L developed her auditory vantage point first (prior to school and the visual learning of month names), while the visual vantage point was developed later (at school when month names were visually presented). We suggest that prior to school, she mapped month names to spatial locations where January, February, March were on her right, April in front, and May, June, July on her left, with the rest of the months trailing away from her. In school however, month names would likely be printed on the blackboard with January, February, and March, depicted in a left-to-right fashion. Therefore, in order for L to reconcile the different spatial organization of her original auditory representation (from right to left), with the visual representation (typically from left to right), she needed to reverse her MVP to align the newly acquired visual month representation with her original auditory representation (see Jarick *et al.*, 2009 for a more detailed discussion).

Related to the notion that synaesthetes have superior visual imagery abilities (Price, 2009), these default perspectives of L's MVPs could be analogous to the canonical viewpoint we all portray in memory of certain objects in the world (i.e., exemplars). For instance, when a word first triggers an image of an object, this object will likely be mentally viewed from a vantage point that conveys the most visual information, however once in working memory most individuals are able to flip and rotate that object around to view it from different angles. This ability to visually mentally rotate objects and representations might also be true for L, where she defaults to her preferred MVP according to the inducer (visual or auditory), but then is able to take other perspectives with some additional cognitive effort (although this is purely speculation at this point). Thus, it would be interesting to investigate whether or not spatial forms rely on working memory for navigation, or whether some other mechanism is at work. On a related note, it would be interesting to examine whether MVP changes are the product of the individual moving within their synaesthetic space, or caused by the synaesthete mentally rotating their time–space (see Sagiv *et al.*, 2006 for a discussion). The synaesthete (L) that we have studied extensively here described her change in MVP as if she moves within her space, but she has been the only synaesthete examined thus far.

Intriguingly, one can imagine how being able to change MVP might be advantageous when trying to remember important dates and appointments. For example, the appointments catalogued in the months furthest away from L's preferred vantage point (i.e., at April) and possibly even out of sight (i.e., December) could be brought into view and made clear if L changed her MVP to be in front or beside December. Indeed, researchers are beginning to document the cognitive advantages associated with having synaesthesia. For example, Simner *et al.* (2009) showed that synaesthetes outperform non-synaesthetes on tasks related to their spatial calendars, such as memory for events, ability to manipulate real or imagined objects in three-dimensional space, and visual memory retrieval. Likewise, Mann *et al.* (2009), as well as Brang *et al.* (2010) showed that synaesthetes perform better on spatial learning tasks when they involve spatial forms congruent with their time–space representations, than incongruent tasks. Thus, there does seem to be a cognitive advantage associated with synaesthesia. An intriguing next step might be to examine whether or not some synaesthetic-like associations could be taught in the general population that might afford similar advantages.

In closing, this study was the first to investigate the speed at which a synaesthete could take different MVPs within their internally generated spatial calendar. We demonstrated that L could do so rapidly – randomly from trial to trial and within 150 ms. Overall, we provided further evidence to support spatial forms as a type of synaesthesia by demonstrating that month names could automatically orient attention to spatial locations within L's spatial calendar, at least in one synaesthete. This study adds to the existing research that has already shown time–space representations to be highly consistent and experienced since childhood. Here we support the third defining characteristic of synaesthesia that spatial forms can be elicited *automatically*, and extend our findings to further show that properties of the inducer can *automatically* elicit changes in MVP, and in L's case, depending on whether the inducer is seen or heard. This ability for the synaesthete (L) to navigate within her time–space representation is yet another astonishing characteristic that clearly sets synaesthetes and non-synaesthetes apart.

References

Brang, D., Teuscher, U., Ramachandran, V. S., & Coulson, S. (2010). Temporal sequences, synaesthetic mappings, and cultural biases: The geography of time. *Consciousness and Cognition*, *19*, 311–320.

Crawford, J. R., & Garthwaite, P. H. (2005). Testing for suspected impairments and dissociations in single-case studies in neuropsychology: Evaluations of alternatives using Monte Carlo simulations and revised tests for dissociations. *Neuropsychology*, *19*, 318–331.

Cytowic, R. E. (2002). *Synesthesia: A Union of the Senses (2nd ed)*. Cambridge: MIT Press.

Cytowic, R. E., & Eagleman, D. M. (2009). *Wednesday is Indigo Blue: Discovering the brain of synaesthesia*. Cambridge, MA: MIT Press.

Dixon, M. J., Smilek, D., & Merikle, P. M. (2004). Not all synaesthetes are created equal: Projector versus associator synaesthetes. *Cognitive, Affective, & Behavioural Neuroscience*, *4*, 335–343.

Eagleman, D. M. (2009). The objectification of overlearned sequences: A new view of spatial sequence synaesthesia. *Cortex*, *45*, 1266–1277.

Friesen, C. K., & Kingstone, A. (1998). The eyes have it! Reflexively orienting is triggered by nonpredictive gaze. *Psychonomic Bulletin & Review*, *5*, 490–495.

Galton, F. (1880). Visualized numerals. *Nature*, *21*, 252–256.

Gevers, W., Reyvoet, B., & Fias, W. (2003). The mental representation of ordinal sequences is spatially organized. *Cognition*, *87*, B87–B95.

Gheri, C., Chopping, S., & Morgan, M. J. (2008). Synaesthetic colours do not camouflage form in visual search. *Proceedings of Biological Science*, *275*, 841–846.

Hubbard, E. M., Piazza, M., Pinel, P., & Dehaene, S. (2005). Interactions between number and space in parietal cortex. *Nature Reviews Neuroscience*, *6*, 435–448.

Hubbard, E. M., Ranzini, M., Piazza, M., & Dehaene, S. (2009). What information is critical to elicit interference in number-form synesthesia? *Cortex*, *45*, 1200–1216.

Jarick, M., Dixon, M. J., Stewart, M. T., Maxwell, E. C., & Smilek, D. (2009). A different outlook on time: Visual and auditory month names elicit different mental vantage points for a time-space synaesthete. *Cortex*, *45*, 1217–1228.

Jonides, J. (1981). Voluntary versus automatic control over the mind's eye's movement. In J. Long & A. Baddeley (Eds.), *Attention and Performance IX* (pp. 187–203). Hillside, NJ: Erlbaum.
Kuhn, G., & Kingstone, A. (2009). Look away! Eyes and arrows engage oculomotor responses automatically. *Attention, Perception, and Psychophysics*, *71*, 314–327.
Mann, H., Korzenko, J., Carriere, J. S. A., & Dixon, M. J. (2009). Time-space synaesthesia—A cognitive advantage? *Consciousness and Cognition*, *18*, 619–627.
Price, M. C. (2009). Spatial forms and mental imagery. *Cortex*, *45*, 1229–1245.
Price, M. C., & Mentzoni, R. A. (2008). Where is January? The month-SNARC effect in sequence-form synaesthetes. *Cortex*, *44*, 890–907.
Sagiv, N., Simner, J., Collins, J., Butterworth, B., & Ward, J. (2006). What is the relationship between synaesthesia and visuo-spatial number forms? *Cognition*, *101*, 114–128.
Seron, X., Pesenti, M., Noel, M., Deloche, G., & Cornet, J. A. (1992). Images of numbers, or "when 98 is upper left and 6 is sky blue". *Cognition*, *44*, 159–196.
Seymour, P. H. K. (1980). Internal representations of months: An experimental analysis of spatial forms. *Psychological Research*, *42*, 255–273.
Simner, J., Mayo, N., & Spiller, M. (2009). A foundation for savantism? Visuo-spatial synaesthetes present with cognitive benefits. *Cortex*, *45*, 1246–1260.
Smilek, D., Callejas, A., Dixon, M. J., & Merikle, P. M. (2007). Ovals of time: Time-space associations in synaesthesia. *Consciousness and Cognition*, *16*, 507–519.
Tang, J., Ward, J., & Butterworth, B. (2008). Number forms in the brain. *Journal of Cognitive Neuroscience*, *20*, 1547–1556.
Van Selst, M., & Jolicoeur, P. (1994). A solution to the effect of sample size on outlier elimination. *The Quarterly Journal of Experimental Psychology Section A*, *47*, 631–650.
Warner, C. B., Juola, J. F., & Koshino, H. (1990). Voluntary allocation versus automatic capture of visual attention. *Perception and Psychophysics*, *48*, 243–251.

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