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Religion and action control: Faith-specific modulation of the Simon effect but not Stop-Signal performance

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ABSTRACT

Previous findings suggest that religion has a specific impact on attentional processes. Here we show that religion also affects action control. Experiment 1 compared Dutch Calvinists and Dutch atheists, matched for age, sex, intelligence, education, and cultural and socio-economic background, and Experiment 2 compared Italian Catholics with matched Italian seculars. As expected, Calvinists showed a smaller and Catholics a larger Simon effect than nonbelievers, while performance of the groups was comparable in the Stop-Signal task. This pattern suggests that religions emphasizing individualism or collectivism affects action control in specific ways, presumably by inducing chronic biases towards a more "exclusive" or "inclusive" style of decision-making. Interestingly, there was no evidence that religious practice affects inhibitory skills.

1. Introduction

Humans do not passively await external stimuli to execute reflex-like responses to them but, rather, actively explore their environment and carry out intentional actions to reach their goals. The recent two decades have shed considerable light on the control processes that adapt and configure the necessary cognitive systems to the goals and tasks at hand. The common idea is that control processes parameterize lower-level perceptual, memory, and action-related processes in such a way that relevant stimulus events are attended to and appropriate actions are performed (e.g., Logan & Gordon, 2001; Monsell, 1996). What is not yet known, and commonly not even discussed, is where the necessary parameter values are coming from and how control processes "know" which values to pick. In other words, it remains unclear who or what is controlling, or at least informing cognitive-control processes.

An obvious possibility is that learning processes play an important role in shaping cognitive control and, perhaps, in creating individual control profiles. For instance, there is increasing evidence that individualistic and collectivistic cultures lead to specific biases of visual attention towards local versus global aspects of visual displays and scenes, respectively (e.g., Boduroglu, Shah, & Nisbett, 2009). However, even though this might be taken to imply a systematic impact of culture-specific learning on cognitive control, the concept of culture is very general (e.g., Heine, 2008) and it is practically impossible to specify which behavioral rules are to be acquired in order to count as a member of a given culture. This renders it notoriously difficult to predict which control parameters might be affected and how. As argued by Colzato, van Beest, et al.

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(2010), religions are much better suited for that purpose. The rules defining them are often laid down in sacred, publicly accessible writings and interpreted to meet everyday-life requirements by experts and mediators (like rabbis, priests, and vicars), who are also actively involved in practicing procedures and rituals that are teaching the rules to active believers.

Given that religions differ with respect to the behavioral rules they developed, they would be expected to affect cognitive-control parameters in different, religion-specific ways (Hommel & Colzato, 2010). In particular, one would expect that practicing a religion biases the preferred values of control parameters to a range that is likely to generate behavior that is approved by one's religious environment. First evidence that this might indeed be the case was reported by Colzato, van den Wildenberg, and Hommel (2008), who compared well-matched Dutch neo-Calvinists and Dutch atheists brought up in the same country and culture. A hallmark of Dutch neo-Calvinism is the concept of sphere sovereignty, which emphasizes that each sphere or sector of life has its own responsibilities and authority, and stands equal to other spheres. This concept has penetrated Dutch culture and caused a considerable "pillarization" (segregation) of Dutch society. Applying the concept to everyday life has established the idea that, in a nutshell, everyone should "mind his or her own business". Colzato et al. speculated that shaping one's behavior to fit with the sphere sovereignty concept would lead to an increased attentional focus on detail rather than the broader context. If so, neo-Calvinists should focus more on the local (rather than the global) aspects of perceived events than atheists—a hypothesis that was confirmed by means of Navon's (1977) global–local task. Consistent with the idea that religion biases individuals towards particular attentional control parameters, Colzato, van Beest, et al. (2010) compared Italian Roman Catholics with Italian seculars and Israeli Orthodox Jews with Israeli seculars. Given that Catholicism and Judaism emphasize social solidarity, Catholics and Orthodox Jews were expected to show a larger global precedence effect than otherwise comparable nonbelievers—which they did. Along the same lines, Taiwanese Buddhists, notorious for their emphasis on "compassion" with the physical and social context, showed a larger global precedence effect than Taiwanese Atheists (Colzato, Hommel, van den Wildenberg, & Hsieh, 2010) while Dutch neo-Calvinists exhibited greater difficulty to attend to two successive visual events than Dutch Atheists (Colzato, Hommel & Shapiro, 2010).

Taken together, these studies show that particular religions seem to exert rather specific effects on information processing by biasing attention towards local or global stimulus aspects. In the present study, we asked whether this is a specific perceptual-attentional effect or a more general bias of cognitive control. Control processes should be able to target several processing stages but not just the selection of a particular level of visual stimulus features. This is why we were interested to see whether religious practice is also associated with differences related to rather "late" processing stages, like response selection and response inhibition—processes that are separable from input-selection processes targeted by the global–local task (Hommel, 1997; Johnston, McCann, & Remington, 1995).

A particularly well-suited task to tap into response selection is the Simon task, which can be assumed to provide a rather pure measure of the emergence and resolution of response conflict (for overviews, see Hommel, 2011; Proctor, 2011). In this task, participants carry out spatially defined (e.g., left and right) responses to non-spatial stimulus features (e.g., blue and green color patches) presented on randomly varying locations (e.g., left and right). Performance is better with spatial stimulus–response correspondence, that is, if the stimulus location happens to match with location of the correct response (Simon & Rudell, 1967)—the so-called Simon effect. The Simon task, and conditions with stimulus–response non-correspondence in particular, introduce a high degree of response conflict, as evident from frequent response errors and electrophysiological observations (e.g., Hommel, 1996). Let us now consider how this uncertainty might be resolved and how this resolution might be modulated by religious practice.

Fig. 1 indicates a common way neural decision-making is modeled. Making a decision between the alternative responses A and B (such as a left or right response) is commonly assumed to involve competition between the representations of the alternatives, as indicated by the mutual inhibitory links in the figure (connection 2), and some sort of top-down support for the alternative that fits the current goals best (connection 1; for a review, see Bogacz, 2007). If stimulus and response correspond in terms of space, there is no conflict whatsoever and the representation of the correct response should be the most activated response alternative. In the case of non-correspondence, however, both response alternatives will be activated, one through the "intentional" route (connection 1) and the other through the spatial stimulus code (Kornblum, Hasbroucq, & Osman, 1990). Mutual inhibition (connection 2) will reduce the total activation of the correct response alternative, at least as long as the incorrect alternative is active, and thereby delay the correct response or even induce an error. This problem is resolved the earlier and the more likely the more top-down support of the correct alternative (connection 1) is provided.

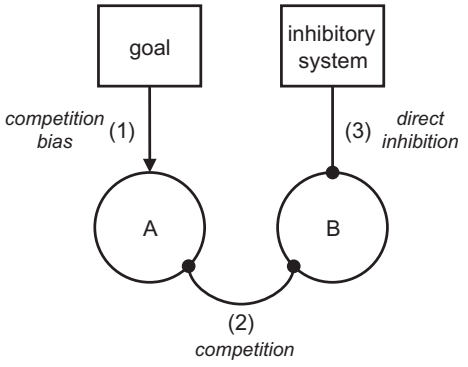

Fig. 1. Possible mechanisms involved in decision-making. The goal-relevant alternative A is supported by the goal representation (1) but competes with choice alternative B through mutual inhibition (2). Instead of the competition bias provided by the goal (1), or in addition to that, the goal-irrelevant alternative B might be suppressed by an inhibitory system (3).

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Let us now consider the possibility that individuals can differ with respect to the strength of both top-down support and mutual (local) inhibition. Evidence for this possibility comes from research on the cognitive effects of bilingualism. Other than monolinguals, bi- and multilinguals are continuously facing the problem of cognitively keeping the languages they master apart, so to prevent mixing up words from different languages in the same sentence or utterance (Bialystok & Craik, 2010). Colzato, Bajo, et al. (2008) suggested that this might lead to a relatively "exclusive" configuration of attentional control parameters, which amounts to a relatively strong top-down support for words from the currently spoken language (connection 1) and relatively strong local inhibition between response alternatives (connection 2), such as words from different languages. If that configuration would become chronic, so the suggestion of Colzato, Bajo, et al. (2008), it might generalize to other, non-language tasks. Indeed, bilinguals have been reported to show a reduced Simon effect (Bialystok, Craik, Klein, & Viswanathan, 2004)—which fits with the idea that bilinguals benefit from stronger top-down support and/or more local inhibition between response alternatives.

Applying these considerations to Calvinists results in exactly the same prediction: If we consider that Calvinism is associated with or even favors a local attentional focus over the processing of the broader context (Colzato, van den Wildberg, et al., 2008), and if we assume that this induces a chronic, generalizable bias towards a more "exclusive" response control configuration, Calvinists should have acquired a comparatively strong top-down support route (connection 1) and more pronounced local inhibition (connection 2).[1] If so, Calvinists should show a smaller Simon effect than Atheists. In Experiment 1, we tested this prediction by comparing Dutch Calvinists and Atheists in a standard Simon task.

We also considered an alternative theoretical account of conflict resolution in the Simon task. Even though the top-down bias represented by connection 1 in the figure could explain why and how people are able to pick the correct response even in the face of response competition, alternative accounts have been suggested (e.g., Dempster, 1992; Harnishfeger, 1995). In particular, Ridderinkhof (2002) has considered the possibility that incorrect responses are directly suppressed. Hence, rather than supporting and selectively strengthening appropriate responses, an inhibitory system might prevent inappropriate responses from interfering and being executed (connection 3). If so, a possible difference in the size of the Simon effect between Calvinists and Atheists might not be due to stronger/more selective top-down support but rather reflect more efficient response inhibition. Given that religions like Calvinism provide rather strict rules to regulate everyday behavior, including the prohibition of numerous activities, it is not unreasonable to consider that practicing these religions might lead to a general improvement of inhibition skills. Indeed, McCullough and Willoughby (2009) have claimed that religious people may be better in inhibiting "wrong thoughts" than nonbelievers and are thus less likely to commit crimes and misconduct. To assess this possibility, we also included a comparison of Calvinists and Atheists in the Stop-Signal task developed by Logan and Cowan (1984). This task requires the intentional suppression of already planned actions and can thus be considered a relatively direct measure of inhibitory abilities (as indicated by connection 3). If we would find an effect of religion on the Simon effect and if this effect would be accompanied by a similar effect in the Stop-Signal task, this would suggest an account of the former in terms of inhibition skills (connection 3). In contrast, if he would find an effect on the Simon task but no effect in the Stop-Signal task, this would suggest an account in terms of selective top-down support (connections 1 and 2).

2. Experiment 1

In Experiment 1, we compared the performance of Dutch neo-Calvinists and (non-baptized) Atheists, brought up in the same country and in the same cultural setting, in the Simon task (Simon & Rudell, 1967) and the Stop-Signal task (Logan & Cowan, 1984). If Calvinists are having a chronic bias towards a relatively "exclusive" configuration of attentional control parameters, we would expect them to show a less pronounced Simon effect than Atheists. If they do, a similar effect pattern in the Stop-Signal task would indicate that this is due to more efficient response inhibition, whereas the absence of such an effect would suggest more selective top-down support of competition-challenged response alternatives.

2.1. Method

2.1.1. Participants

Forty Dutch young healthy adults (tested in Leiden, the Netherlands) were compensated for their collaboration and constituted the two groups: Dutch Calvinists (all members of the "Gereformeerde Vrijgemaakte" Church of Gouda) and Dutch Atheists (never baptized). All participants were matched for ethnicity (100% Caucasian), culture, age, and IQ—see Table 1 for demographic data and religious routines. All participants were educated in the country they

[1] Top-down bias of competition and local inhibition are different mechanisms that have dissociable effect on behavior (Bogacz, 2007) and are likely to rely on separable brain circuits and neurotransmitter pathways (cf., Cools, 2008). Logically speaking, it might thus very well be that practice (be it language- or religion-related) affects only one of the two mechanisms or that it affects both mechanisms in different ways. However, behavioral measures did not yet allow for determining which of these possibilities is most likely to hold—the reason being that the action of one of these mechanisms can be mimicked by the other. For instance, bilingual practice might make top-down support for words in one currently spoken language stronger and, thus, more selective without necessarily affecting the strength of inhibitory links between alternatives. Conversely, it might only affect the strength of these links without improving top-down support. Both types of effects would provide bilinguals with a more "exclusive" control set. Given the available neuroscientific evidence that the neural and neuromodular pathways underlying top-down support and inhibition interact very closely and can even compensate each other in the face of impairments (Cools, 2008), we suspect that practice does affect both mechanisms alike. However, we emphasize that the present study does not speak to this issue and does not allow one to distinguish between contributions from the two mechanisms—which is why we treat them here as equivalent.

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Table 1
Demographic characteristics and religious routines of participants, and performance on the Simon and Stop-Signal tasks in Study 1 (Dutch Calvinists and Atheists) and Study 2 (Italian Roman Catholics and Seculars). Standard errors of reaction times and error rates are presented in parentheses. Hypotheses-related effect sizes in bold.

	Experiment 1 Dutch		Experiment 2 Italian	
	Calvinists	Atheists	Catholics	Seculars
Variables				
Sample *N* (M:F)	20 (10:10)	20 (10:10)	18 (2:16)	18 (4:14)
Age (years)	23.4 (2.1)	24.2 (1.6)	24.8 (5.7)	25.9 (4.2)
Raven IQ	110.6 (4.8)	112.8 (4.6)	111.7 (5.2)	113.9 (5.7)
Baptized (Yes:No)*	20:0	0:20	18:0	14:4
Communion (Yes:No)**			18:0	0:18
Daily prays**	1.7 (0.9)	0 (0)	0.5 (0.5)	0 (0)
Simon task				
Correspondence				
Reaction times (ms)	378 (12.5)	374 (10.7)	469 (12.5)	478 (12.5)
Error rates (%)	5.9 (0.7)	3.0 (0.7)	0.4 (0.2)	0.9 (0.2)
Non-correspondence				
Reaction times (ms)	411 (12.3)	417 (11.1)	513 (12.5)	508 (12.9)
Error rates (%)	10.9 (1.5)	9.4 (1.5)	2.2 (0.4)	2.0 (0.4)
Simon effect				
Reaction times (ms)**	**33**	**43**	**44**	**30**
Error rates (%)	5.0	6.4	1.8	1.1
Stop-Signal task				
Go reaction TIME (ms)	377 (9.0)	361 (9.0)	500 (26.0)	521 (26.0)
Error rates (%)	2.1 (0.4)	1.5 (0.4)	0.6 (0.2)	0.7 (0.2)
Stop-Signal reaction times (ms)	**207** (37.5)	**206** (25.1)	**233** (32.3)	**232** (36.1)

Significant group difference.
* $p < 0.05$.
** $p < 0.01$.

lived in, were exposed to the same educational style and institutional type, and reported similar social-economical background. Written informed consent was obtained from all participants after the nature of the study was explained to them; the protocol and the remuneration arrangements of 8 Euro or course credits were approved by the respective institutional review board.

2.1.2. Apparatus and stimuli

The experiments were controlled by a computer running under Windows™, attached to a 17-in. monitor (96 dpi with a 120 Hz refresh rate).

2.1.2.1. Simon task. A small (.5 cm) dark gray square was presented throughout an experimental block in the center of the computer screen and served as a fixation point. The stimulus on each trial was either a green or a blue circle (1.5 cm in diameter) that was presented to the left or right of fixation. The color and location of the circle varied randomly but both colors and locations appeared equally often across the experiment. Viewing distance was about 60 cm. Responses were made by pressing the "z" or "?" button of the computer keyboard with the left or right index finger, respectively.

2.1.2.2. Stop-Signal task. Participants were required to react quickly and accurately by pressing the left and right key in response to the direction of a left- or right-pointing green arrow (go trials) of about 3.5×2.0 cm with the corresponding index finger. Responses were made by pressing the "z" or "?" of the QWERTY computer keyboard with the left and right index finger, respectively.

2.1.3. Task and procedure

2.1.3.1. Simon task. The task consisted of a 25-min session in which participants made speeded discriminative responses to the color of the circle. Participants operated both response keys by responding left to a green circle and right to a blue circle. Circles stayed on the screen until the response was given or 1500 ms has passed. Intervals between subsequent stimuli varied randomly but equiprobably, from 1750 to 2250 ms in steps of 100 ms. Participants were to ignore the location of the stimulus and to base their response exclusively on its color. Responses were to be given as fast as possible while keeping error rates below 15% on average; feedback was provided at the end of a trial block. The task consisted of six blocks of 60 trials (with all conditions being equiprobable), the first of which served as a practice block.

2.1.3.2. Stop-Signal task. The task consisted of a 30-min session in which participants completed a version of the Stop-Signal task adopted from Colzato, van den Wildenberg, and Hommel (2007). Arrows were presented pseudo-randomly for maximal 1500 ms, with the constraint that they signaled left- and right-hand responses equally often. Arrow presentation was response-terminated. Intervals between subsequent go signals varied randomly but equiprobably, from 1250 to 1750 ms in steps of 125 ms. During these interstimulus intervals, a white fixation point (3 mm in

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diameter) was presented. The green arrow changed to red on 30% of the trials, upon which the choice response had to be aborted (stop trials). A staircase-tracking procedure dynamically adjusted the delay between the onset of the go signal and the onset of the stop signal to control inhibition probability (Levitt, 1971). After a successfully inhibited stop trial, Stop-Signal delay on the next stop trial increased by 50 ms, whereas the Stop-Signal delay decreased by 50 ms on the next stop trial when the participant was unable to stop. This algorithm ensured that motor actions were successfully inhibited in about half of the stop trials, which yielded accurate estimates of the time needed to successfully stop a response (the so-called Stop-Signal Reaction Time or SSRT) and compensates for differences in choice reaction time (RT) between participants (Band, van der Molen, & Logan, 2003). The stop task consisted of five blocks of 104 trials each, the first of which served as a practice block to obtain stable performance.

All participants were tested individually and completed the intelligence test, the Simon task and the Stop-Signal task. Individual IQ was determined by means of a 30-min reasoning-based intelligence test (Raven's Standard Progressive Matrices: SPM (Raven, Court, & Raven, 1988). The SPM assesses the individual's ability to create perceptual relations and to reason by analogy independent of language and formal schooling; it is a standard, widely-used test to measure Spearman's g factor and of fluid intelligence in particular.

2.1.4. Statistical analysis

Independent *t*-tests were performed to test age and IQ differences between the groups. In the Simon Task mean RTs and (square-rooted) error percentages were analyzed by means of ANOVAs using spatial stimulus–response Correspondence (versus non-correspondence) as within- and Group as between-participants factor. In the Stop-Signal Task mean RT for go trials (i.e., trials without a stop signal) and SSRT for Stop-Signal trials were individually calculated to index response execution and response inhibition, respectively. SSRTs were analyzed separately by means of univariate ANOVAs with Group as between-subjects factor. Moreover, Pearson correlation coefficients were computed between the individually calculated Simon effect and mean SSRT for Stop-Signal trials in order to test whether the Simon task and the Stop-Signal Task shared underlying inhibitory mechanism. A significance level of $p < .05$ was adopted for all tests.

2.2. Results

2.2.1. Participants

No significant group differences were obtained for age, $t = 1.40$, $p > .05$, or intelligence, $t = 1.60$, $p > .05$.

2.2.2. Simon task

The RT and error rates analyses showed a main effect of Correspondence, $F(1, 38) = 226.88$, $p < .0001$, MSE = 127.172, $\eta_p^2 = 0.85$ (RTs) and $F(1, 38) = 42.52$, $p < .0001$, MSE = 15.434, $\eta_p^2 = 0.53$ (errors), which was modified by Group in RTs but not in errors, $F(1, 38) = 4.39$, $p < .05$, MSE = 127.172, $\eta_p^2 = 0.10$ (RTs) and $F < 1$ (errors). Both Atheists and Calvinists showed a significant main effect of Correspondence, $F(1, 19) = 149.82$, $p < .0001$, MSE = 142.943, $\eta_p^2 = 0.89$ (RTs) and $F(1, 19) = 24.16$, $p < .05$, MSE = 16.888, $\eta_p^2 = 0.56$ (errors); $F(1, 19) = 82.62$, $p < .0001$, MSE = 129.402, $\eta_p^2 = 0.81$ (RTs) and $F(1, 19) = 18.39$, $p < .001$, MSE = 13.981, $\eta_p^2 = 0.49$ (errors), respectively. These main effects indicated that responses were faster and more accurate with stimulus–response correspondence (376 ms and 4.4%) than with non-correspondence (414 ms and 10.8%, respectively). As expected, however, this correspondence effect was reliably smaller in Calvinists than it was in Seculars (see Table 1).

2.2.3. Stop-Signal task

Both Calvinists and Atheists were able to stop their responses on Stop-Signal trials successfully about half of the time, 52.5%, *SE* = 0.9%, and 50.7%, *SE* = 0.7%, respectively, indicating that the dynamic tracking algorithm worked. The percentage of choice errors on go trials was equally low in both Groups.

Neither mean RTs on go trials nor SSRTs were modified by Group, *F*'s < 1, indicating that Calvinists reacted about equally fast as Atheists and showed SSRTs that were in fact almost identical to those of the Atheists.

2.2.4. Correlations

No significant correlation was found between mean SSRT for Stop-Signal trials and Simon effect, $r(40) = -.125$, $p = .44$.

2.3. Discussion

As expected, the Simon effect was smaller in Calvinists than in Atheists. This suggests that the impact of religion goes beyond input selection (as assessed by means of the global–local and other attentional tasks) but affects action control as well. Given that input selection and response selection are dissociable processes in principle (Johnston et al., 1995) and that the global–local effect temporally overlaps with, but is dissociable from the Simon effect in particular (Hommel, 1997), the present interaction between Simon effect and religious orientation confirms our expectation that religion affects a rather broad range of cognitive processes. Interestingly, however, the two groups did not differ in their performance on the Stop-Signal. This suggests that religious practice does not improve inhibitory skills, at least as far as neo-Calvinism and response inhibition are concerned. This is also consistent with the lack of correlation between the size of the Simon effect and SSRT. Rather, it seems that religion operates on top-down regulation (connection 1) and/or local competition (connection 2).

3. Experiment 2

The observation of a reduced Simon effect in Calvinists suggests that religious practice helps managing interference from competing response alternatives. We have argued that this effect should be specific to Calvinists, because their believe system emphasizes individualism

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and focusing attention on one's own societal pillar, which in turn should induce a rather "exclusive" cognitive-control configuration. Other interpretations are possible, however. For instance, it might be that religious individuals are trying to do better and to try harder, which might have helped Calvinists to ignore the irrelevant information more effectively. It might also be that religious practice trains people in focusing on the present task in general, so that our finding might not reflect the specific impact of Calvinism.

To demonstrate that the reduced Simon effect is indeed a specific result of Calvinistic religious training calls for the consideration of another religion, a religion that is less likely to induce the same kind of cognitive-control configuration. Along the lines of our reasoning that it is the individualistic emphasis of Calvinism that is responsible for the reduced Simon effect, the obvious choice would be a religion that puts more emphasis on social solidarity and the group context than Calvinism does—such as Roman Catholicism (cf., John Paul, 1987). Given that Catholics in the Netherlands are concentrated in the southern part of the country, close the borders to Belgium and Germany (which is likely to bring in cultural factors as possible confounds), we carried out the second experiment in Italy. As the Dutch culture is penetrated by Calvinism so is Italian culture immersed by Catholicism, so that the relation between culture and religion can be considered comparable to Experiment 1.

If it is true that Calvinism and its emphasis on individual responsibility and duties is responsible for the cognitive-control configuration that made Calvinists show a smaller Simon effect than Atheists, one would expect that Roman Catholicism with its emphasis on social solidarity and group thinking leads to the opposite effect: the Simon effect should be more pronounced in Catholics than in otherwise comparable nonbelievers[2]. The tasks in which these two groups of participants were tested were identical to those used in Experiment 1.

3.1. Method

Thirty-six Italian young healthy adults (tested in Bologna, Italy) were compensated for their collaboration and constituted the two groups of 18 participants each: Italian Roman Catholics and Italian Seculars (people who grew up in a laic environment). As in Experiment 1, all participants were matched for ethnicity, culture, age, and IQ—see Table 1 for demographic data and religious routines. All participants were educated in the country they lived in, were exposed to the same educational style and institutional type, and reported similar social-economical background. Written informed consent was obtained from all participants after the nature of the study was explained to them; the protocol and the remuneration arrangements of 5 Euro were approved by the respective institutional review board. The remaining procedure was as in Experiment 1.

3.2. Results

3.2.1. Participants

No significant group differences were obtained for age, $t = 0.89$, $p > .05$, or intelligence, $t = 1.53$, $p > .05$.

3.2.2. Simon task

The RT and error rates analyses showed a main effect of Correspondence, $F(1, 34) = 115.48$, $p < .0001$, MSE = 216.684, $\eta_p^2 = 0.77$ (RTs) and $F(1, 34) = 21.22$, $p < .0001$, MSE = 1.882, $\eta_p^2 = 0.38$ (errors), which was modified by Group in RTs but not in errors, $F(1, 34) = 4.25$, $p < .05$, MSE = 216.684, $\eta_p^2 = 0.11$ (RTs) and $F(1, 34) = 1.168$, $p > .05$, MSE = 1.882, $\eta_p^2 = 0.03$ (errors). Separate ANOVAs confirmed that the Correspondence effect was reliable in both Catholies and Seculars: $F(1, 17) = 61.17$, $p < .0001$, MSE = 290.541, $\eta_p^2 = 0.78$ (RTs) and $F(1, 17) = 14.19$, $p < .01$, MSE = 2.143, $\eta_p^2 = 0.45$ (errors), and $F(1, 17) = 57.21$, $p < .0001$, MSE = 142.827, $\eta_p^2 = 0.77$ (RTs) and $F(1, 17) = 7.23$, $p < .05$, MSE = 1.620, $\eta_p^2 = 0.29$ (errors); respectively. The overall main effect indicated that responses were faster and more accurate with stimulus–response correspondence (473 ms and 0.6%) than with non-correspondence (510 ms and 2.1%, respectively). However, as expected, Roman Catholics exhibited a more pronounced correspondence effect than Seculars (see Table 1).

3.2.3. Stop-Signal task

Participants in both Groups were able to stop their responses on Stop-Signal trials successfully about half of the time: Roman Catholics (51.9%, $SE = 0.9\%$) and Seculars (51.5%, $SE = 0.7\%$), indicating that the dynamic tracking algorithm worked. The percentage of choice errors in go trials was equally low in the two Groups.

Mean RT on go trials was not modified by Group, $F < 1$, indicating that Catholic participants reacted equally fast as Seculars. SSRTs followed the same trend and were not modified by Group, $F < 1$.

3.2.4. Correlations

No significant correlation was found between mean SSRT for Stop-Signal trials and Simon effect, $r(36) = -.098$, $p = .57$.

3.3. Discussion

The finding that Roman Catholics show a larger Simon effect than Seculars demonstrates that religion does not always reduce the effect but seems to modulate its size depending on the type of religious practice. As in Experiment 1, we found no evidence for any impact of religion on performance in the Stop-Signal task and no relationship between this performance and the size of the Simon effect. This suggests that Catholic practice induces a rather general bias towards a less "exclusive" action-control configuration without affecting direct response inhibition.

[2] As it is almost impossible to find culturally well-integrated Italian participants that are not baptized, we used Italian Seculars (i.e., baptized Catholics that did not receive any religious training) as control group. Even though this group provides a fair comparison with the practicing Italian Catholics we investigated, it cannot be directly compared with the (not baptized) Dutch Atheists from Experiment 1.

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4. General discussion

The aim of our study was to test whether religious practice can not only affect spatial (Colzato, van Beest, et al., 2010; Colzato, van den Wildenberg, et al., 2008) and temporal (Colzato, Hommel & Shapiro, 2010) characteristics of stimulus selection but also control processes devoted to action regulation, such as response selection and response inhibition. We expected that the emphasis of Calvinism on segregation and detail would induce a particular configuration of control parameters that does not only favor the processing of local information (Colzato, van Beest, et al., 2010; Colzato, van den Wildenberg, et al., 2008) but that might also increase the control focus on, and thus provide extra facilitation of the correct response . If so, one would expect a comparatively better ability to withstand, handle, and overcome response competition, as induced in the Simon task. Indeed, Calvinists showed a significantly smaller Simon effect than otherwise well-matched Atheists in Experiment 1. We also expected that members of a religion that emphasizes the social context, like Roman Catholicism, would acquire a configuration of control parameters that does not only spread visual attention across space (Colzato, van Beest, et al., 2010) and time (Colzato, Hommel & Shapiro, 2010) but that is also less selective with regard to competing response representations. If so, one would expect a larger Simon effect in Catholics than in nonbelievers, which is exactly the pattern obtained in Experiment 2.

In both experiments there was no evidence whatsoever that religious orientation would affect response inhibition as assessed by means of the Stop-Signal task. This has three implications of theoretical relevance. First, it implies that religious practice does not operate on control processes concerned with the direct inhibition of incorrect response tendencies but, rather, on the top-down support of wanted actions and/or the degree to which alternative responses compete. Whereas practicing Calvinists seem to possess a more selective top-down bias and/or stronger local competition than nonbelievers, the opposite seems to be the case in Roman Catholics, who seem to have a less selective top-down bias and/or weaker local competition.

Second, this dissociation between Calvinists and Roman Catholics suggests that McCullough and Willoughby's (2009) conclusion that religiosity per se increases cognitive control may be too general under at least some circumstances. It is conceivable that religiosity as such (irrespective of the specific religion being followed) is sufficient to predict particular types of behavior under religion-relevant conditions, such as in moral dilemmas or in the face of temptations—the type of behavior McCullough and Willoughby were focusing on. However, predicting effects on control under more mundane conditions, such as in the laboratory tasks employed in the present study, seems to require the consideration of the specific religious practice participants have enjoyed. At least with respect to the Simon effect, our findings imply that religiosity can be associated with both increased and decreased control, depending on the particular religious history of the participant.

Third, the fact that faith modulated the size of the Simon effect without having any impact on response inhibition, together with the absence of any correlation between the size of the Simon effect and SSRT, casts considerable doubt on the idea that response inhibition plays a crucial role in the Simon task, as claimed by Ridderinkhof (2002). To the contrary, the result pattern we obtained is consistent with Egner and Hirsch's (2005) assumption that response competition in Simon and Stroop-like tasks is resolved through top-down support of the correct response along the lines of connection 1 in our Fig. 1.

Before we turn to the question of exactly how religious practice might modulate cognitive-control processes, it is important to consider the status of religion as a causal factor. For obvious reasons the membership of individuals in religious groups and institutions is beyond experimental control. Accordingly, it is impossible to rule out the contribution of self-selection: particular individuals might be genetically equipped with, or may have acquired particular control strategies and may have picked the religious belief that fits best with these strategies. If so, our study would not have assessed the impact of religious practice, at least not in a pure form, but rather, the contribution of such pre-religious factors. Even though this is a logically tenable scenario, there are a number of reasons that seem to render it relatively unlikely. For one, in Europe the membership to religions is commonly acquired by birth, where the religious orientation of parents is passed to the newborn. Changing this state of affairs commonly requires majority, which means 16–18 years of not self-chosen religious practice for an individual. This practice does not rule out that the inherited faith comes with a compatible genetic equipment (that the newborn shares with his or her parents), but it does question the relevance of self-selection and pre-religious practice for the present findings. For another, even genetic predispositions are likely to require particular environmental conditions to fully develop, which would render religious practice at least a crucial variable in the emergence of a particular cognitive-control configuration. Hence, even though we cannot rule out the contribution of other factors, there are reasons to assume that religious practice is at least very important for the generation and maintenance of the cognitive-control profiles that our study was aiming at.

If we thus consider that religious practice is at least a marker, if not a source of individual differences in cognitive control, how might these differences emerge? Obviously, Calvinism and Catholicism differ in many ways and many of those differences may be responsible for the observed variation in the size of the Simon effect. However, we have suggested that the emphasis on segregation and individual responsibility versus social solidarity is a particularly salient difference that strongly shapes the everyday behavior of the respective members of these religious communities (for a similar consideration in the context of cultural differences, see Nisbett & Miyamoto, 2005). According to cognitive-control theories, the generation of intentional behavior requires the appropriate configuration of the cognitive system, which has been taken to amount to the parameterization of lower-level sensorimotor processes

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(Logan & Gordon, 2001). Religious training and practice through parents, peers, and the relevant authorities (teachers, priests, etc.) will lead to the selective reward of some but not other behaviors. As these behaviors were generated by particular control parameters, this implies selective reward for some but not other parameter values, which is likely to establish a preference for some parameter values over others. Along these lines, religious practice can systematically induce biases towards particular value ranges of control parameters.

One of the parameters considered by Logan and Gordon (2001) controls the attentional set (parameter *c*) including the focusing on the global versus local characteristics of registered stimuli. If we assume that Calvinists are selectively rewarded for showing behaviors that are generated with the help of a relatively local attentional focus, they are likely to have acquired a preference for a range of parameter values close to the "local" end of the continuum. If so, it is not surprising that they are relatively faster to process stimulus information that requires such local values—as demonstrated by Colzato, van den Wildenberg, et al. (2008). If we assume the opposite for Catholics, which are likely to be selectively rewarded for the consideration of the broader context, which again requires parameter values from the "global" end of the continuum, it makes sense that they have more difficulties to process local information (Colzato, van Beest, et al., 2010).

Another parameter of Logan and Gordon's (2001) model relates to the degree of competition between alternative responses (parameter *K*), which amounts to the strength of the mutually inhibitory links between alternatives in decision-making (connection 2 in Fig. 1). If people have control over the amount of response competition they can tolerate, selective reward for tolerating more or less competition might also establish acquired biases towards one or the other end of the parameter-value continuum. A strictly individualistic religion like Calvinism is likely to provide reward for gating out social "distraction" or "noise" in decision-making and, thus, establish a bias towards a relatively low tolerance for competition. According to our model considerations, this would induce strong inhibitory links between alternatives, which again would imply a strong local suppression of conflicting information. This is likely to improve performance in the Simon task but has no obvious bearing for Stop-Signal performance—which fits with the outcome patterns we observed. Conversely, a religion that emphasizes the consideration of a lot of social information, like Catholicism, might be expected to induce a bias towards relatively weak inhibitory links between alternatives. Even though that might be useful in tasks that require the integration of large amounts of information, it would be expected to hamper performance if part of that information is conflicting with the decision-making process, like in the Simon task.

It remains to be seen whether and to what degree these two hypothesized parameters, or the biases therein, are independent or correlated, and it remains to be investigated what other parameters might be affected by religion. But what seems to be clear is that specific religious practices have a rather specific impact on human cognition. This impact can be demonstrated to generalize beyond religious settings and activities, and to affect everyday behavior. Apparently, adopting and living according to a particular faith leads to the acquisition of particular cognitive-control styles and corresponding biases in parameters that regulate not only the intake of information (Colzato, van Beest, et al., 2010; Colzato, van den Wildenberg, et al., 2008) but, as the present study shows, the style and efficiency of decision-making as well.

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