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## **Do Martial Artists Make Decisions Faster?**

**A Study Comparing Martial Arts Practitioners to Non-Practitioners on a CRT Task.**

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### **Abstract**

Split-second decision-making is of vital importance to many aspects of human existence, from life-and-death scenarios to sports. Studies have shown expert advantage in a given field on choice reaction time tasks within the area of expertise. Still, no conclusive studies on differences in this skill between athletes and non-athletes have been made on CRT tasks for general stimuli. The aim of this study was to establish if there are differences between martial arts practitioners and non-practitioners on a choice reaction time task to generic stimuli not related to expert knowledge. The results showed no significant advantage to martial artists regarding speed and an advantage to non-practitioners on accuracy. However, it was argued that the differences could either be a result of speed-accuracy trade-off or because of methodological fallacies in the study. Therefore, the study suggests that future research could achieve significantly different results by improving upon the methodology of this study.

Keywords: martial arts, decision-making, stroop, choice reaction time, reaction time, exercise

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### **Sammanfattning**

Snabba beslut är centralt för många aspekter av människans existens, från sport till frågor om liv och död. Forskning har visat att experter har ett övertag gällande choice reaction time-uppgifter som är relaterade till deras expertområde. Trots detta har inga studier slutgiltigt kunnat konkludera huruvida en skillnad finns mellan atleter och icke-atleter på en CRT-uppgift för generella stimuli. Syftet med denna studie var att etablera om det finns skillnader mellan kampsportsutövare och icke-utövare på en choice reaction time-uppgift för generella stimuli, oberoende av deras expertkunskaper. Resultaten visade inga signifikanta fördelar gällande hastighet för kampsportsgruppen, men däremot ett signifikant resultat till fördel för icke-utövargruppen på träffsäkerhet. Detta kan antingen vara en fråga om "speed-accuracy trade-off" eller till följd av metodologiska brister i studien. Således föreslår studien att framtida forskning kan få tydligare resultat genom att förbättra metodologin som använts i studien, snarare än att avfärda hypoteserna.

Nyckelord: kampsport, beslutsfattande, stroop, choice reaction time, reaktionstid, träning

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## **Introduction**

Split-second decision-making has long been essential to human existence. Whether it is avoiding predators, hunting, more modern occurrences such as driving cars, or combat, the split-second decisions we make can have an immense impact on our chances of survival. The core issue of these high-speed scenarios is that they tax our attention and decision-making skills. However, these skills can be trained (Wellner, 2014; Wilimzig, Ragert, & Dinse, 2012; Huang, Menozzi, Beldi, & Brand, 2019). Similar stress on attention and decision-making skill is found in competitive martial arts. Though the situations with highest risk for split-second decision-making are those of military and police operations, martial arts provide a comparatively low-risk scenario with similar challenges. An experienced police officer can draw a firearm and put an accurate shot on target within two seconds (Hontz, 1999), with boxers being able to initiate and complete a punch in approximately half a second (Kimm & Thiel, 2015). In real life violent encounters, decisions on whether or not deadly force should be used take place within the span of a few seconds (Fridell & Binder, 1992; Helsen & Starkes, 1999; Johnson et al., 2014; Campbell, Roelofs, Davey, & Straker, 2013). These decisions are both quick and complex (Binder & Scharf, 1980; Bayley, 1986; Johnson et al., 2014). Research has shown the advantages of expert knowledge on decision making within a specific field, such as karate or volleyball (Mori, Ohtani, & Imanaka, 2002; Chamberlain and Coelho, 1993). The question of whether or not one general factor of split-second decision-making, that can improve this ability across multiple areas of expertise at once, exist remains unanswered. Therefore, the aim of this study is to clarify the relationship between reaction time, decision-making and martial arts. More specifically, it strives to establish whether there are differences on choice reaction time (CRT) for generic stimuli between martial arts practitioners and a non-practitioner control group.

## **Background and theory**

Hick's law states that CRT is slower than simple reaction time due to the fact that there are options, and that this effect is directly correlated with the number of options given, thus an increased number of options leads to a longer reaction time (Hick, 1952). Miller and Low (2001) also showed that motor preparation was the same regardless of the type of reaction time test being used, thus arguing that increased reaction time for CRT is due to longer processing time.

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Another factor to take in to account when discussing CRT is speed-accuracy trade-off, which states that when higher speed of response is required, more error responses are given, whereas when more time is given, the answers will be more correct, for a review regarding speed-accuracy trade-off, see Heitz (2014).

Studies and reviews on the subject have shown the complex nature of the neurobiological basis for decision-making, as well as the difficulties with pinpointing specific areas of the brain that play an active role in decision-making itself (Gold, & Shadlen, 2007; Glimcher, 2003). For simple decisions movement selection makes up a large part of the brain mechanisms (Gold, & Shadlen, 2007). Studies on simple decision-making and motor function in primates have shown three principal categories for behavior and that all three have a common origin in a single mechanistic process on the physiological level (for a review, see: Glimcher, 2003). As for more abstract decisions, where movement might not be necessary there are suggestions that the prefrontal cortex does the heavy lifting with abstract forms of planning (For a review, see: Gold, & Shadlen, 2007).

Reaction time and decision-making, measured by choice reaction time tasks, are both abilities which have been shown to be trainable, with cognitive training in the form of computer-based training programs (Simpson, Camfield, Pipingas, Macpherson, & Stough, 2012) and video games (Ballesteros et al., 2015), as well as with sensory stimulation (Wilimzig et al., 2012). Furthermore, Furuya, Shintani, Miyagi, and Nakagaki (2012) showed sustained attention as an important factor in choice reaction time behavior. Attention and vigilance are further cognitive functions that have been shown to improve with appropriate training (Szalma, Daly, Teo, Hancock, & Hancock, 2018).

Beyond immediate training of cognitive abilities, physical activity has been shown to have an important relationship with cognitive functioning. As shown in a review by Kramer and Colcombe (2018), exercise has a broad effect on cognitive function in older adults, with the largest benefits shown in executive functioning. Neuroimaging has also shown structural changes in the brain, notably in frontal and parietal regions which were connected to selective attention. Regular physical exercise has also been shown to have a positive relationship with reaction time in older adults, when compared to peers who exercise only irregularly (Li, Huang, Liu, Chang, & Hung, 2019), suggesting either a facilitation for improvement in reaction time or a mediating effect on possible cognitive decline with age. However, the effects of aging on choice reaction time tasks specifically remain unclear (Commodari &

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Guarnera, 2008). Furthermore, a study by León, Ureña, Bolaños, Bilbao, and Oña (2015) showed that even relatively short exercise programs could lead to improvement on simple and choice reaction time tests for older adults, an effect that was amplified when combined with cognitive training. Furthermore, different types of exercise or sport have been shown to have effect on different types of cognitive skills. When compared, opened and closed skill sports differed in auditory reaction time, and in anticipatory skill, but not in visual reaction time, suggesting skill improvements are specific to the practiced sport (Nuri, Shadmehr, Ghotbi, & Attarbashi Moghadam, 2013).

Decision-making in martial arts has been studied and approached in several different ways, such as the constraints that affect a boxer's decision to punch, and what type of punch to use, such as reachability (Hristovski, Davids, Araújo, & Button, 2006), perceptual-motor training and gaze behavior in karate fighters (Milazzo, Farrow, & Fournier, 2016), and anticipatory skills in karate experts as compared to novices (Mori et al., 2002; Rosalie & Müller, 2013). These studies, while different in approach, all showcase the importance for martial artists to be able to quickly take in relevant information and base a decision on that information. Both the study by Mori et al. (2002) which used a karate based choice reaction time task, and the study by Rosalie and Müller (2013), which used visual occlusion in situ to test participants anticipation, show that expert karate practitioners outperform novices on the tasks given, attributing this to improved anticipatory skills as a result of experience and expert knowledge. Expert advantage in decision making speed on realistic tasks has also been suggested as a result of superior confidence in their expert field (Chamberlain & Coelho, 1993).

However, the mainstay of studies on martial arts have been tested on expert and novice practitioners of the same martial art. Therefore, it has not been possible to determine if there are differences present between different martial arts or between martial artists and non-practitioners at a group level. It is possible that basic sensory functioning is in fact superior for practitioners on a group level, but such research has yet to be made. There are also studies that report a slight, but significant, speed advantage to athletes compared to novices on choice reaction time tasks with generic stimuli (Nougier, Azemar, & Stein, 1992; Whiting & Hutt, 1972). This could indicate a difference between martial arts practitioners and non-practitioners on CRT and basic sensory level split-second decision-making. However, newer studies have not been able to replicate this result (Mori et al., 2002; Martinez de Quel,



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Bennett, López, Zapico, & Saucedo, 2015). As such the current understanding of whether martial arts lead to an improvement in generalized CRT or not is equivocal. The study by Martinez de Quel et al. (2015) did however indicate that both age and sex could be significant predictors for CRT.

In a comparison between karate training and mindfulness training on mental well-being and cognitive performance, stroop was used in the original sense as a measure of inhibition (Jansen, Dahmen-Zimmer, Kudielka, & Schulz, 2017). Stroop tests include visual stimuli on a computer screen, often presented as either words in color-coding or varying shapes. The participant is then under instruction to click or not click as fast as possible when certain conditions of color-coding are met. Stroop, therefore, measures both correct and incorrect responses as well as false positives, i.e. when the person fails to inhibit their response to a stimulus they are instructed not to react to. However, stroop style tests have been extensively used in decision-making studies, showing its applicability to the subject of split-second decision-making. In the study of football players (Fortes et al., 2019; Smith et al. 2016) stroop tasks were used as a way of assessing mental fatigue before football specific decision-making tasks. A study on cyclists (Spindler, Allen, Vella, & Swann, 2019) used stroop as a measure for decision-making performance. The stroop task was also used by Li et al. (2019) as a measure of reaction time. As operationalized in this study, the act of split-second decision-making can be broken down into four steps: (1) registering sensory input, (2) deciding how to act based on this information and then finally (3) initializing and (4) performing the chosen behavior. As stroop tests involve these components it was deemed a suitable choice to measure this basic form of decision-making.

Even though the results on expert versus novice differences in CRT are inconclusive there is some support for the existence of expert advantage in CRT tasks. Thus, this study aims to widen the field by establishing (1) if martial artists are faster than non-martial artists on generic stimuli CRT task and (2) that martial artists are more accurate than the non-martial artists. By using participants from a wide array of martial arts, as compared to previous studies mainly focusing on differences within one given art, this study hopes to garner new insights on the effects of martial arts training as a whole rather than in-art differences.

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## Method

### Participants

The participants consisted of one martial arts group (n=33) with one participant excluded due to misinterpreted instructions leaving (n=32). The group consisted of 26 males, 6 females (81.3% male, mean age =33.78, SD age=14.3) and one control group (n=32) consisting of 13 males and 19 females (59.4% female, mean age=33.94, SD age=15.27). Descriptive data was collected on all participants (table 1). The majority of the martial artists were recruited and tested at their martial arts gym (n=30) while three were recruited through personal connections to the authors and tested at Lund university or at the subject's home. Selection of control group participants was primarily convenience based as the authors recruited amongst students at Lund university (n=18), acquaintances (n=6), family (n=7), and posters on campus (n=1). Subjects provided informed, written consent and filled out a questionnaire pertaining to age, sex, practiced martial art (appendix A) and/or sports, how long they had trained, if they have competed or compete, as well as any medical information that could affect the test.

Table 1 - *Descriptive data for the sample groups, measuring level of education based on the Swedish education system, and number of years spent training any sport.*

	Level of education (n)			Training any sport (years)		
	Grundskola	Gymnasium	Eftergymnasial	Range	Mean	Standard deviation
Experiment (n = 32)	1	12	19	2-55	13.16	12.208
Control (n = 32)	1	14	17	0-18	2.31	5.233

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## **Materials**

**Questionnaire and consent form.** The questionnaire (appendix B and C) distributed before testing was constructed by the authors. It included questions pertaining to age, gender, current employment, highest completed education, practiced martial art(s), if the participant has competed, other sports, and medications or other things that could affect the results. Levels of completed education was measured according to the Swedish educational system, with educational levels being defined as “grundskola” (approximately between the ages 7-15), “gymnasium” (between the ages 16-19), and “eftergymnasial” (post-gymnasium studies, primarily university level studies).

The consent form (appendix D), also constructed by the authors, started with a brief description of what the purpose of this test was. This was followed by a first description of how the actual test would be performed. Thereafter, information regarding data collection and usage as well as voluntary and informed participation were presented and signed by the participant.

**The test.** The stroop test was constructed using OpenSesame (v. 3.2.8). The test started with presenting the instructions, in large part repeating the instructions given in the consent form, as well as an example. The arrow keys on the authors’ computers were used to represent four colors: green, red, blue and yellow, to correspond to the colors and words used for the test items. The keys were also color-coded using stickers. The computerized test included 10 practice items, half with instruction to match the arrow key to the word appearing on the screen regardless of what color it was written in and the other half with instruction to match the corresponding key to color regardless of what word was written. In the main test the total number of items amounted to 120. These items were then divided in four equally large blocks, separated by instructional pages. Of these blocks two had instructions to follow color regardless of what word was written and two to follow words regardless of what color they were written in. Participants were randomly assigned to either start by following color or start by following words. They were instructed to answer as quickly and as correctly as possible. Items within the blocks were displayed in a randomized order and were displayed until an answer was given. A new item was then displayed after a 1400ms delay.

## **Procedure and design**

Participants were invited to sit and start with reading and signing the consent form, then to fill out the questionnaire. If they had any questions they were able to ask them before

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continuing to the computerized tests where they were presented with on-screen instructions. They were encouraged to ask clarifying questions regarding the test, the questionnaire or the consent form throughout this process. When testing began at least one of the test administrators (authors) remained close by to allow technical difficulties or arising questions to be dealt with while the other recruited more participants or kept possible disturbances to a minimum. The computerized test took between 15-20 minutes and the forms around 5-10 minutes. As a result of recruitment circumstances most of the control group tests took place either in group rooms at university or at home. Tests for the martial arts group were mainly performed at their gyms.

The design of this study most closely resembled that of a quasi-experimental design (Shadish & Cook, 2002). The pre-test questionnaire aimed at minimizing these confounding factors by enabling control of the factors presented under the questionnaire headline above.

### **Ethics**

This study has followed the APA guidelines for ethical research. All participants were given information regarding both the study's purpose as well as practical information regarding the testing. They were also informed that they could at any point choose to withdraw their participation. Written consent was collected from all participants. Information regarding publication of results and finished paper was given. All collected data was handled confidentially, and access was only available to the authors. Furthermore, the data was only used for the current study, and destroyed after the study was completed.

Since the current study is a master's thesis, with no formal ethical approval from the ethics board, certain questions that were considered could not be systematically collected and analyzed. For example, questions regarding participants health, as these questions would have required such approval. Such questions were still asked, but only used as a means of exclusion where needed. This could still be discussed from an ethical standpoint as it is possible that the question itself poses a risk of affecting participants.

Otherwise, the form of testing performed was considered non-harmful. A risk that was discussed, especially considering the martial artists, was that giving out test results could entail competition and negatively affect participants in the case they were not happy with their results. Therefore, a certain amount of caution was used regarding giving out results, especially on location at gyms. However, the risk was deemed small enough considering that the sport in question is competitive in nature, thus this did not prevent testing.

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### **Statistical analysis**

Statistical analysis of the collected data was done using IBM SPSS Statistics (version 26.0). Statistical significance was set as  $p < 0.05$ . Initial analysis of the data showed a few extreme outliers within both groups and thus outliers were excluded for relevant analyses with the exclusion criterion of two standard deviations. This resulted in the exclusion of the results of five participants. All tests were run on both the full sample as well as samples with outliers removed. Results are presented for the groups with outliers excluded unless otherwise stated.

Normality of the data was assessed using the Shapiro-Wilk test. Independent sample t-tests were used for mean comparison between the groups on the dependent variables mean correct responses, mean reaction time, and mean reaction time for correct responses. For cases where normality could not be assumed the nonparametric Mann-Whitney U test was also used to test the effect.

Effect of covariates on the dependent variables were checked for using a multivariate linear regression analysis for collected continuous variables that met the criteria for such analysis. Categorical covariates were checked for using independent sample t-tests.

The speed-accuracy trade-off was checked for using a bivariate linear regression with reaction speed as a predictor for correct responses. In testing the full sample, the assumption of homoscedasticity was violated. However, in testing with outliers excluded this assumption could be met.

## **Results**

### **Main findings**

**Correct responses.** In comparison between the sample groups on mean amount of correct responses equal variances could not be assumed, thus both independent t-test as well as the nonparametric Mann-Whitney U test were used. Outliers beyond two standard deviations were excluded for the analysis. Independent sample t-test showed a significant difference between the experiment group ( $M = 0.929$ ,  $SD = 0.064$ ) and the control group ( $M = 0.968$ ,  $SD = 0.027$ ) with  $t(38.788) = 3.033$ ,  $p = .004$ . Due to the difference in standard deviation Glass's delta was used to calculate effect size,  $d = 1.44$ . The Mann-Whitney U test also showed a significant difference between the experiment group ( $Mdn = 0.95$ ) and the control group ( $Mdn = 0.98$ ) with  $U = 293$ ,  $p = .02$ . The analysis was also run on the full sample, without exclusion of outliers, and showed similar significant results.

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**Mean reaction time.** Comparing the groups on mean response time, measured in milliseconds, no significant difference could be found between the experiment ( $M = 919.4$ ,  $SD = 237.2$ ) and the control group ( $M = 990.6$ ,  $SD = 237.2$ ) with  $t(59) = 1.172$ ,  $p = .246$ . Cohen's  $d$  shows a small effect size,  $d = 0.3$ . Analysis with the full sample yielded similar results with no significant difference.

**Mean reaction time on correct responses.** The groups were also compared on mean response time only for correct responses, measured in milliseconds. This comparison showed no significant difference between the experiment ( $M = 907.4$ ,  $SD = 226.4$ ) and the control group ( $M = 988.3$ ,  $SD = 237.9$ ) with  $t(59) = 1.36$ ,  $p = .179$ . Cohen's  $d$  effect size is small with  $d = 0.35$ . Analysis with the full sample once again yielded similar results with no significant difference between the groups. See table 2 for overview.

Table 2 - Means and standard deviations for martial artists and control group, after removal of outliers, for mean number of correct responses, mean reaction time, and mean reaction time on correct responses. Significance value of  $t$ -test analysis of between group differences.

Group		Mean number of correct responses		Mean reaction time		Mean reaction time on correct responses	
		Outliers excluded	$p$ - value	Outliers excluded	$p$ - value	Outliers excluded	$p$ - value
Martial artists	M	0.929		919.4		907.4	
	SD	0.064		237.2		226.4	
			.004		.246		.179
Control	M	0.968		990.6		988.3	
	SD	0.027		237.2		237.9	

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### Secondary findings

**Speed-accuracy trade-off.** The results of the bivariate linear regression on the full sample shows that mean reaction time predicts variation in correct responses by 7.4%. The model was significant with  $F(1,62) = 4.983, p = .029$ . However with the exclusion of outliers the new model explains 0% of variation in the dependent variable,  $F(1,58) < .001, p = .997$ .

**Regression analysis.** Correlation of covariates with the dependent variables showed that age correlated strongly with reaction time and reaction time for correct responses, and that frequency of training correlated with correct responses. Furthermore, a close to significant correlation was found for total amount of years trained on all dependent variables. Results of the multivariate regression analysis showed age to be the strongest predictor for

Table 3 – Report of multivariate analysis for full model (Explained variance, F-value and significance value), as well as separate predictors used in the models (unstandardized b, standard error, beta value and significance value).

	Predictors				Full model		
	b	SE	$\beta$	p	R-squared	F	p
<b>Reaction time</b>					.460	24.685	<.001
Age	11.66	1.7	.670	<.001			
Years trained	-6.27	2.54	-.241	.016			
<b>Reaction time correct responses</b>					.437	22.487	<.001
Age	11.16	1.7	.652	<.001			
Years trained	-6.11	2.54	-.239	.02			
<b>Correct responses</b>					.124	4.088	.022
Years trained	-.001	.001	-.303	.033			
Frequency of training	-.003	.004	-.086	.539			

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mean reaction time ( $\beta = .670, p < .001$ ). For mean reaction time for correct responses age was once again the strongest predictor with  $\beta = .652, p < .001$ . The strongest predictor for mean amount of correct responses was total amount of years trained in any sport with  $\beta = -.303, p = .033$ . See table 3 for report of all predictors.

**Comparison of means.** Independent sample t-tests were used to check for an effect of the categorical covariates gender and level of education on the dependent variables. No significant differences could be found between or within groups on the variables. Sample sizes were too small in other categorical variables such as types of martial arts practiced for proper statistical analysis.

## Discussion

### Results discussion

The results show no significant difference in reaction time between the experiment group and control group which is in line with the studies done by Mori et al. (2002) and Martinez de Quel et al. (2015), but not with the results of the studies by Nougier et al. (1992) and Whiting and Hutt (1972). Contrary to the hypotheses the results show an advantage to the control group in terms of accuracy, which differs from previous studies on the subject, this might, however, best be explained by speed-accuracy trade-off. Furthermore, qualitative observation during testing suggests that the control group was more careful and concerned about answering correctly, while the martial arts group was more competitive and focused more on speed. Unfortunately, the number of participants was too small to perform proper statistical analysis of potential differences between different martial arts. Although the results are non-significant, there are important implications to be discussed as a result of this study.

Firstly, note must be taken of the fact that effect sizes for the reaction time analysis were quite small even after correction for outliers. The difference found in milliseconds when it comes to reaction time in the non-outlier group, though small and not significant, suggest a study with more power could detect a significance showing a faster martial arts group. Especially considering that any differences in reaction time during a stroop task can be expected to be small and has been small in previous studies of a similar nature (Fortes et al., 2019; Smith et al., 2016; Li et al., 2019). Since differences in speed are in milliseconds and the variance in accuracy is so small in terms of percentages important questions are raised. The expected differences cannot be assumed to be large even if they are found to exist. Since the form of decision-making studied here takes place within the span of a couple of seconds,



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the CRT differences measured in milliseconds will inevitably be miniscule. Yet, if there are significant improvements to be made, even a few milliseconds can prove essential in both life-or-death and sport scenarios. In the case of martial arts, this could mean the difference between managing to hit your opponent or not, or avoiding getting hit yourself. Thus, despite insignificant results, this study can garner valuable insights regarding the limitations and possibilities of future research on the subject of CRT.

Secondly, frequencies on covariate factors showed a significant difference regarding sex and amount of overall training between the groups. Regression analysis suggest that years trained is a significant predictor for CRT performance, this seems to be in line with earlier studies and reviews such as Kramer and Colcombe (2018), Li et al. (2019), and León et al. (2015) that show a connection between exercise and performance on CRT tasks. However, the results of the current study also show years trained to be a negative predictor for amount of correct responses. This could simply be a case of speed-accuracy trade-off wherein a larger focus on giving quick responses leads to a larger number of error responses, this would then imply that individuals with more experience training put a larger stress on being fast rather than being correct. An important note concerning these results of the current study is that the correlation between years trained and the dependent variables was merely near significant, this has to be taken into consideration when assessing the validity of the results. Age is also shown to be a negative predictor for speed in the current study, this is in line with the result presented by Martinez de Quel et al. (2015). Unlike Martinez de Quel et al. (2015), the current study could find no correlation between sex and performance on CRT tasks. However, the sex imbalance would have to be tested with a larger, more equal sample to be dismissed with any certainty. The significant results on age and years trained in sports implies that it is important for future research to answer questions on the impact of more general training than martial arts on CRT and if the apparent effect of aging is (1) confirmed and (2) in anyway offset by exercise – martial arts or otherwise.

### **Methodological discussion**

Primarily, the martial artists had more distractors in their testing environment than the control group: with noise from training, music, people talking and even on a few occasions interrupting them, as well as having performed varying degrees of physical exercise at the time of testing. The control group on the other hand was exclusively tested in calmer environments, usually in a room with only them and the authors present. Unfortunately, this

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proved inevitable as a result of the practical aspects of recruitment. Even with this notable environmental difference between the groups, raw data suggests there might be something to the hypotheses regarding CRT for martial artists that can be found with more rigorously controlled setting for the test and higher power. This would also allow to control the significant results on accuracy as well, to see if the difference remain after environmental factors are controlled for.

The utilized hardware consisted of two different type laptops which could have resulted in different results. The main potential issue with hardware is that the refresh rate of the used computer would cause a certain delay, in the realm of a few milliseconds, this is not an issue when using one computer, or when similar hardware is used, as any delay caused by hardware would be the same for all participants. However, when different hardware is used the delay could potentially vary to an extent that could influence the results. Furthermore, the arrow keys of the computers used were differently sized and located. While initial trials before testing ensued did not show any significant difference in hardware performance this possibility might not have been fully controlled for as it was not recorded on which computer the participants performed the test. Generally, assignments alternated between the two computers in an attempt to gain a somewhat equal split. This was not always achievable as certain testing was done on separate locations at the same time. Thus, more rigorous control of which computer was used would have allowed for statistical control of differences to exclude it as a confounder, even though certain control was exerted over computer distribution.

An important matter of discussion is validity and whether or not the operationalization of split-second decision-making as choice reaction time is a sufficient one. Furthermore, it can be discussed if it is accurately measured through the use of stroop tests. Though it captures aspects of the phenomenon, it must be considered that it is more complex than what can be captured by this definition. This invites caution to interpreting the results of the current study as well as carries implications for future research.

Reliability can be questioned on the basis of the questionnaire constructed by the authors as well as the utilized stroop test. Since both were constructed by the authors for use in this study, neither one can be considered as established forms of testing. Although a small pilot test was performed it would be possible to further strengthen test reliability by more rigorous pre-test trials or by utilizing established tests and questionnaires. This did, however,

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prove difficult as the psychological study of martial artists is still limited and while some similar studies have been done, no instruments applicable to the current study were available to the authors.

Furthermore, certain confounders were not included as covariates since they did not occur to the authors until after the fact. Most prominent amongst these is the presence of computer and gaming experience, which has been shown “reduces reaction times and [to] be positively associated with accuracy” (Greitemeyer, 2019; Bediou et al., 2018). This could have implications for the current experiment as some participants brought this up during testing, as such it is reasonable to assume at least these participants had computer or gaming experience that could have had an effect on their performance. It is, however, unknown whether other participants had similar experience or not, as this was not properly controlled for, hence it is possible that this and other confounders factor into the results. Furthermore, the questionnaire gave the opportunity for participants to share information regarding medication or medical conditions that would prevent a just result on the test. Considering no ethics board approved of the use of health data, this information was not systematized or stored for any use, but exclusively used to enable exclusion of participants not suitable for the test and to give the participants an opportunity to opt-out of testing. However, considering that attention plays an important role in CRT behavior (Furuya et al., 2012) it is plausible to consider that diagnoses or medication affecting attention would be a confounding factor. It is possible that as information on health was not systematically collected and analyzed it was not properly controlled for. This raises questions as to the external and internal validity of the questionnaire and how well it controls for confounding factors within the frame of the quasi-experimental design, and thus also the generalizability of the study.

Finally, as a result of the recruitment process and the composition of the two groups, consideration and discussion concerning pre-existing differences is vital to understanding the results. As previously stated, there was no randomization regarding groups, as a necessity stemming from the hypotheses regarding martial arts. Recruitment had to be directed to relevant and available practitioners, which inevitably means the study is subjected to potential selection biases. Questions arise regarding whether or not the martial arts gyms used for recruitment are representative of martial artists as a whole. An attempt was made to gather practitioners from a multitude of disciplines and with varying degrees of both training and competitive experience, the wisdom of which can be discussed in relation to the effect size

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and statistical power. A clearer focus on one specific martial arts group could have more appropriately controlled for the likely variation inherent between different arts. It is conceivable that the currently used mixed focus could have been ideal if the number of participants in the martial arts group would have allowed for reliable testing of between-group differences of the differing martial arts. This would have allowed for a deeper understanding of which martial arts gave the best training as it is likely that they are not all equal in regard to the hypotheses.

### **Conclusions**

In conclusion, the current results indicate that the null hypotheses need to be kept and the test hypotheses must be dismissed as no significant advantage in speed or accuracy was found in favor of the martial arts group. On the contrary, accuracy was significantly better for the non-martial arts group. Regression analysis on covariates showed that age and years trained was, similar to previous studies, negatively and positively related to speed respectively.

However, the combination of residual confounders, such as the environmental factors, pre-existing group differences, the used operationalization, and the construction of the questionnaire, has severe implications on the study's ability to draw reliable conclusions in regard to the hypotheses. Therefore, we argue that discarding the hypotheses on the basis of these results is premature. Furthermore, it could prove devastating for future efforts in improving split second decision-making if a false negative was to be accepted. The collected data hints at possible differences in speed, but the power level was not sufficient, and confounders not adequately minimized. The study yields relevant insights into future fields of research on the relationship between martial arts and split-second decision making.

### **Future research**

Focus for future research on this subject should primarily fall on methodology. If the environmental factors are controlled, the power increased, operationalizations re-examined and methodological assumptions revisited, the results would more justly reflect reality. Also, further research is necessary to fully understand the relationship between age, years trained, and reaction time.

Any and all improvements that can be made to split-second decision-making, even if measured in tens or hundreds of milliseconds, has the potential to save lives in extreme situations such as fatal accidents, violence, war. Hence, they are worth investigating to their

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fullest. Also, if further study enforces significant difference in accuracy between the control group and the martial artists, exploration of why this is could garner important knowledge on how exercise impacts decision-making quality. It is imaginable that this is a question of speed-accuracy trade off, which would imply that higher accuracy in the control group would mean higher speed in the martial arts group. If that is not the case, understanding of why that is can deepen our understanding of human decision-making skills.

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## Appendix

**Appendix A** - *Descriptive data on frequency of different types of martial arts in the experiment group (some individuals practiced more than 1 type of martial arts).*

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Martial arts	Number of practitioners	Percentage of experiment group
Judo	13	40.6%
Boxing	7	21.9%
Muay thai	6	18.8%
Kickboxing	6	18.8%
Brazilian jiu-jitsu	4	12.5%
Japanese jiu-jitsu	3	9.4%
Mixed martial arts	3	9.4%
Iaido	2	6.3%
Kung fu	2	6.3%
Taekwondo	1	3.1%
Bujutsu	1	3.1%
Karate	1	3.1%
Kobudo	1	3.1%
Krav maga	1	3.1%

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## Appendix B – Questionnaire for martial artists

### Fakta om dig

Ålder:

Kön:    Kvinna    Man    Annat                                   

Utövad kampsport:

Tid du utövat kampsporten (i år)?

Hur många gånger i veckan har du utövat kampsporten?

Har du tävlat? (specificera gärna antal gånger mm.)

Utövar eller har du utövat någon annan sport? Specificera vilken och under hur lång tid.

Tar du några mediciner som kan påverka ditt resultat? (ge exempel)

Sysselsättning:

Högsta avslutade utbildning:

- Grundskola
- Gymnasium
- Eftergymnasial utbildning

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Någonting övrigt som du tänker kan vara bra för testledarna att känna till som kan påverka dina resultat?

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**Appendix C – Questionnaire for control group**

**Fakta om dig**

Ålder:

Kön:    Kvinna    Man    Annat                                   

Utövar du någon sport? I så fall vilken?

Hur länge (i år)?

Hur ofta (exempelvis: flera gånger i veckan eller en gång i månaden)?

Har du tävlat?

Utövar du eller har du utövat någon kampsport?

Tid du i så fall utövat kampsporten?

Tar du några mediciner som kan påverka ditt resultat (exempelvis:)?

Sysselsättning:

Högsta avslutade utbildning:

Grundskola

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Gymnasium

Eftergymnasial utbildning

Någonting övrigt som du tänker kan vara bra för testledarna att känna till som kan påverka dina resultat?

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## **Appendix D** – *Consent form given to all participants*

### **Information om experimentet**

Studien syftar till att undersöka förmågan att fatta snabba beslut.

Du kommer att få se ord och färger. Piltangenterna på tangentbordet kommer representera varsin färg: Röd, Grön, Gul eller Blå. Dessa är även de ord och färger som kommer dyka upp i testet. Beroende på instruktionerna på skärmen ska du antingen sortera efter text (trycka motsvarande piltangent om det står exempelvis "Blå", även om ordet är skrivet i en annan färg) eller att sortera efter färg (trycka motsvarande piltangent för färgen, piltangenten för blå om ordet "Grön" är skrivet med blå text). Det är viktigt att du gör det så snabbt som möjligt och så korrekt som möjligt. Testet startar med ett träningsblock för att ge dig möjlighet att se hur testet går till. Själva testet utgörs sedan av fyra testblock där instruktionerna växlar mellan blocken. Genomförande av testet tar omkring 10-15 minuter i anspråk.

Det är möjligt för dig som deltagare att ta del av studiens resultat när den är färdig genom att kontakta författarna eller söka upp studien på Lund Student Papers med hjälp av författarnas namn. Studien bör ligga uppe i mitten av januari 2020.

### **Samtycke till deltagande**

Nedan ger du ditt samtycke till att delta i den studie där vi undersöker beslutsfattande under stress. Läs noggrant igenom nedanstående punkter och ge ditt samtycke genom att kryssa i rutan och skriva din signatur.

- Jag har tagit del av informationen kring studien och är medveten om hur den kommer gå till och vilken tid den tar i anspråk.
- Jag har fått tillfälle att få mina frågor angående studien besvarade innan den påbörjas och vet vem jag ska vända mig till med frågor
- Jag deltar i denna studie helt frivillig och har blivit informerad om att jag när som helst kan avbryta mitt deltagande utan att behöva förklara varför. Om du väljer att avbryta kommer din data inte att användas.
- Jag ger mitt medgivande till att testledarna lagrar och bearbetar den data som insamlas. Data kommer att hanteras konfidentiellt och i enlighet med rådande etiska principer.
- Jag ger detta medgivande förutsatt att inga andra än de forskare som är knutna till studien kommer att ta del av min data.

Jag har tagit del av informationen och godkänner att min data används i studiesyfte

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**Signatur**

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**Namnförtydligande**