Bachelorthesis:

Effects of kickboxing match fighting on flanker performance

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06-2015
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Keywords

Flanker task
Brain damage
Concussion
Kickboxing
Match fighting
Reaction time

Abstract

Brain damage in athletes is a widely occurring phenomenon that is underreported and difficult to measure. As concussions have an effect on executive functioning it may be possible to use this effect and quantify the severity of the brain trauma. This can be done by using the Eriksen flanker task which we used in an altered version with congruent and incongruent bird shaped arrows for game effect. We used kickboxers to monitor the amount of impact received during a match and looked at differences in flanker effect pre- and –post match. In this experiment we found a significant difference in flanker effect (p = .0042), reaction time (p = .040) and in effiency (p = .020) between the controls and the match group. There were however found no differences between the pre- and post-match measurement. This means that there is a baseline difference between the two groups but evidence for an effect on the flanker task through a match remains elusive. Due to the low amount of participants it can be advisable to look at the flanker-concussion relation with a bigger test battery and complete dataset, as we do not have sufficient pre-match measurements.

Introduction

Imagine yourself being a kickboxer who has been training for months to win a fight. During the fight you think you have a real chance to win, until suddenly you get surprised by a hard punch to the head that knocks you out for a couple of seconds. What would you do? Will you throw in the towel and give up? Despite it probably being better for your health, it could cause harm to your reputation as a fighter and you would lose the fight and lose the cash prize. Or would you continue to fight and increase your risk of brain damage?

Brain damage in athletes is a widely occurring phenomenon. For example, an Australian study of 3207 non-professional rugby players reported approximately eight concussions per 1000 player hours. And with professional players the numbers are even higher. It has been suggested that between 1.6 and 3.8 million concussions per year in the US are related to sports (Khurana & Kaye, 2012). There is a tendency amongst athletes to overexert themselves while playing. This increases the risks of severe injuries. Especially when it comes to brain damage related incidences, there is an underreporting of the damage a player or fighter sustains during their games (Broglio, Macciocchi, & Ferrara, 2007). For there is an overall mentality that states: if you’re able to walk, you’re able to play. It is because of this mentality, and the great difficulty to accurately assess a player's condition on the field (Lovell, Collins, & Bradley, 2004), that the actual prevalence of concussions exceeds the reported amount.

When a concussion or brain damage occurs, executive functioning is affected (Howell, Osternig, Van Donkelaar, Mayr, & Chou, 2013). Executive functioning can be seen as the ability to plan purposeful behaviour flexibly, to react to external stimuli and to prepare oneself to react to these stimuli. The ability to inhibit oneself from a course of action that is habitual and instead execute a different set of behaviour can be tested via various ways like for example a stroop task or a flanker task can be performed (Badzakova-Trajkov, Barnett, Waldie, & Kirk, 2009; Eriksen & Eriksen, 1974; Fan et al., 2009; Howell et al., 2013). These tasks based on conflicts as the stroop task depends on the conflict between the meaning and colour of words, and the flanker task uses a congruent and incongruent situation to cause conflict in ones internally predicted course of action. Eriksen and Eriksen 1974 creates this congruent and incongruent situation by using letters. Participants are told here to look at the middle of seven letters, three letters on either side of the target letter. The target letters were H, K, S and C. H and K required to press a lever to the left and S and C to the right (or opposite). The congruent situation was created to flank the target letters with letters from the same category (congruent) or the other category (incongruent). In later experiments using this flanker effect, arrows were used instead of the letters (Howell et al., 2013; Nieuwenhuis et al., 2006; Van Steenbergen, Band, & Hommel, 2009). Here five arrows are used pointing to the left or right, and the middle letter can either be congruent (facing the same way) or incongruent (facing the opposite way) with the surrounding arrows. This repeatedly changing action pattern tests executive functioning in a relatively fast manner (for greater detail about this flanker task see the methods section). Since there is no effective way yet to quickly and accurately measure sustained brain damage and to determine when the damage has receded to a point that returning to play is justified, the flanker task may come as a solution to this problem.

The goal in this experiment will be to ultimately devise a model to quickly assess the situation an athlete finds himself in after attaining head trauma. But to do this it is imperative to test a few conditions first. First we must gain understanding of how the dynamics between the severity of head trauma and executive functioning take place. Secondly, to realize an effective model we need to know certain character traits and other information about the individuals. For example, sleeping behaviour and

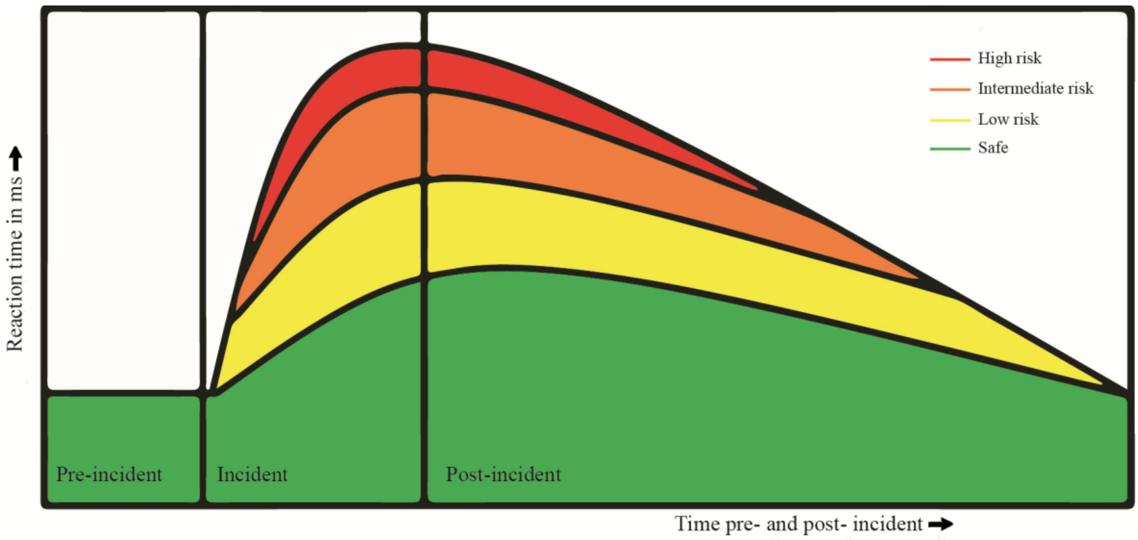

Figure 1: Model of flanker task reaction time (RT). At the time of the incident RT increases and slowly declines over a matter of months to the baseline. How much an athlete's RT increases determines how risky it is to return to play.

impulsiveness can influence flanker task performance (Potts, George, Martin, & Barratt, 2006; Tsai, Young, Hsieh, & Lee, 2005). A questionnaire can be used to pin down these variables and adjust the advice given to the athlete accordingly. After that a scale can be made that determines when a player is safe to resume to the game. Howel et al. (2013) found that brain trauma takes up to two months to resolve itself (even though symptoms disappear between two weeks to one month post injury). So it is within this timeframe that a model has to be made that determines whether an athlete's reaction time (RT) comes back to a healthy baseline. In figure 1 an example is given of what such a model might look like based on our predictions. At first the athlete is at a baseline RT for the flanker task. At the time of the incident that causes the brain trauma, RT will increase and then slowly decline back to its baseline. Depending on the severity of the brain trauma and performance on the flanker task one can estimate the risk an athlete takes when returning back to play. For when the athlete returns too soon the residual damage may cumulate with possible new brain damage, further worsening his condition. In this manner coaches might be able to make an educated decision about whether or not they will let the athlete play.

To test these conditions, kickboxers will be used in this experiment. Because kickboxers are being hit numerous times on the head during a match we can isolate the damage done to the brain. The expectation is that a when a fighter receives more and harder hits to the head the brain damage is more severe and ultimately this will result in a longer RT on the flanker task. They will also need a longer recuperation time than fighters that obtained less damage.

Methods

Participants

Out of a total of 54 participants, 33 responded after being contacted to participate. Of those 33 participants 17 reported to be match fighters. Of those match fighters only six were included in the experiment. This amount of dropouts was due to five match fighters having never responded when tried to be contacted, one participant had been contacted several times but never did the task, one participant had an injury so he then was placed in the control group, one participant's opponent dropped out so went on to be in the control group but never did the third measurement, an error occurred with one participant which kept flanker results from ever being recorded even though questionnaires results were being successfully recorded and two only have done the task once so were excluded.

Out of the 16 participants that started in the control group, three had done the task only once and were therefore excluded from the experiment. Adding the two that dropped out the match group makes a total of 15 participants in the control group and six participants in the match group. Which brings us to a percentage of reject of 36.37% judging from the total of participants with whom contact was successfully initiated after acquiring personal information needed for participation. A clear overview of the flow of participants is given in figure 2.

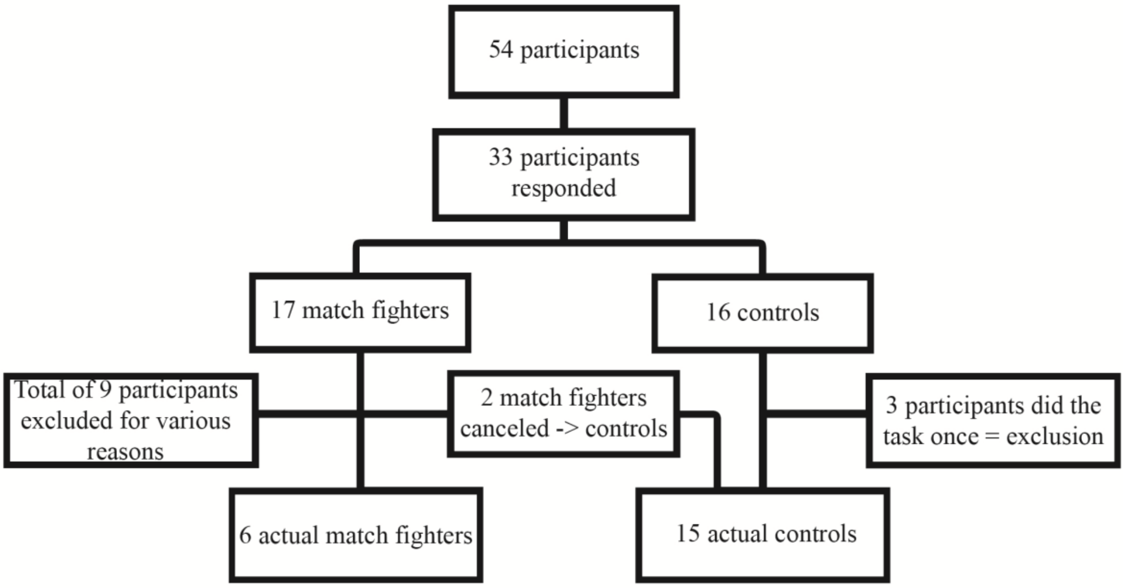

Figure 2: Visual representation of the flow of participants. Out of 54 initial participants a total of 21 remained for actual data analysis. The rest were excluded for insufficient amount of trials done or none at all.

Thus in this study a total of 21 adults (aged ±19 to ±38 with a mean of 26.35) 17 male and 4 female kickboxers were used, with a total of 15 being assigned to the control group and 6 to the match group. Each participant had the skills to train with the match group and a total of 18 out of 21 participants have competed in a match before. These skills are usually determined by the trainer that places the fighter in the match-group of their gym.

Eriksen flanker task

The participants took part in an Eriksen flanker task at four time points. About three days before the match as a practice trial, one day before the match to determine baseline reaction time, one day after the match to determine the actual damage from the match and one month after the match to see the recovery pattern. For easy use, we developed a website that allowed the participants to do the flanker task on their mobile phone and computer.

The Eriksen flanker task consists of a central cue surrounded by four peripheral arrows, as shown in figure 3. The participant is to watch only for the direction in which the middle arrow is pointing and react in such a manner that is fitting. If the middle arrow points left, the participant will strike a key at the left side of the keyboard and so on. If the middle arrow points in the same direction as the surrounding flanker

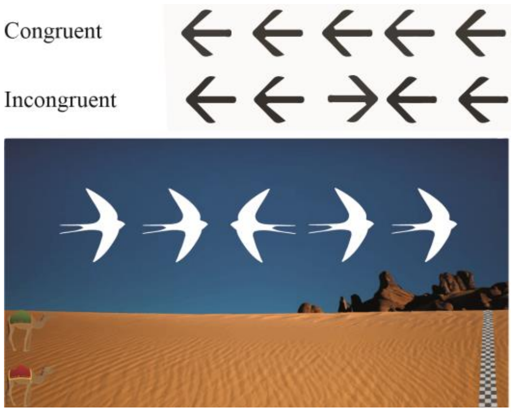

Figure 3: Flanker task arrows. When the middle arrow points in the same direction as its surrounding arrows it is called congruent. If the middle arrow points in the opposite direction, it is called incongruent. Under the arrows a picture is shown as it was in the experiment itself. A game element was added to make the task perform like a camel race. Participants' RT had to be faster than the computers or else their camel won't cross the finish line first. Note that the arrows themselves are an exaggeration of the actual arrows (birds) sizes, and are shown for 800 ms, fixation duration was generated randomly to keep participants focused.

arrow it is called congruent. However if the middle arrow is pointing at the opposite direction this is called incongruent. To make the task more appealing for participants, a game element was added to the task. Participants’ RT’s had to be faster than that of the computer to have their camel cross the finish line first and win the race. For visual effect arrows were replaced by white arrow shaped birds are shown for 800 ms on a desert background as can also be seen in figure 3 Fixation duration was generated randomly to keep participants focused .

Accounting for screen size and distance differences

Because the size of the flanker effect differs with the size of the arrows, relative size of the arrows has to be taken into account as well. When similar sized arrows are at different distances from the eyes, the arrows further away will seem relatively smaller, thus increasing the flanker effect. Think of a participant doing the task on his smart phone instead of his desktop. Generally people hold their phone at about half the distance of the distance they have with their desktop screens. Furthermore, the pixel size on each computer differs slightly amongst each other. So screens with larger pixels will show larger arrows when programmed to contain the same amount of pixels. To counter for these effects participants are asked to place their thumbs on the screen with a full arm’s length when using a desktop or laptop, and with half an arm’s length when using smart phones. And then use a bar to adjust the size of the thumb on the screen to match the thumb of the participant (as can be seen in figure 4). This way, assuming that thumb and arm-size between participants doesn’t differ in a significant manner, relative sizes of the arrows can be countered and the flanker effect will be the same over a variety of devices.

Figure 4: Figure of the bar designed to match a participants thumb.

Questionnaires

Every participant was asked to fill in a Barratt’s impulsiveness test and a questionnaire regarding former head injuries, date of their last match, how strenuous the last and current match was, etc. This might provide a good estimate of their baseline flanker task performance. Furthermore each participant answered a short questionnaire about how they slept and other factors that may have had an influence on the flanker task before each measurement.

Rating the fights

Each fight of each participant was filmed for rating purposes. Ratings were done by a single blind observer, who had not seen the data of the flanker tasks itself. For rating the impact of the punches and kicks to the head of the participants in a kickboxing match direct hits to the head were counted. Then the amount of hits was correlated the flanker performance.

Data analysis

Data were analyzed by a t-test between the congruent and incongruent conditions as well as for the two groups (Match fighters vs. controls) using Microsoft Office Excel 2007. Then a repeated measures ANOVA and two way ANOVA was performed using IBM SPSS statistics version 20. Additionally correlations were calculated between the covariates and the flanker performance using Excel, as well as the p-value calculations for these correlations. Significance was set at $p < .05$.

Results

Functionality of the flanker task, is there really a difference between congruent and incongruent?

A t-test was conducted to compare reaction time in congruent and incongruent conditions. There was a significant difference in the scores for congruent (M = 496.62, SD = 84.22) and incongruent (M = 567,53, SD = 75.88) conditions; $t(20) = 7.39$, p = 3.88*10-7. Mean difference (flanker effect) was 70.91 ms, SD = 43.97. These results indicate a significant difference between the congruent and incongruent condition, as is shown in figure 5. This conforms with previous findings, as Tsai et al. (2005) finds a flanker effect of ±45 ms, Mayr, Awh, Fan et al. (2005) with a flanker effect of 90 ms and Sanders and Lamers (2002) with an effect of 75.41 ms. This similarity in flanker effect tells us that our task itself is functional, and that our data can be compared with that of other studies. In figure 6 a histogram is depicted showing the frequency of the flanker effect.

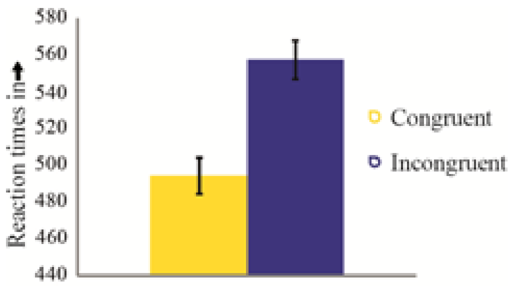

Figure 5: Overall RT of the congruent (M = 496.62, SD = 84.22) and incongruent (M = 567,53, SD = 75.88) conditions; $t(20) = 7.39$, p = 3.88*10-7, with a mean difference (flanker effect) of 70.91, SD= 43.97. These results indicate a significant difference between the two conditions.

Then a t-test was performed to compare efficiency between the congruent and incongruent condition. A significant difference was found here also between congruent (M = 1.99, SD = 0.29) and incongruent (M = 1.62, SD = 0.22) conditions; $t(20) = 9.04$, p = 1.69*10-8. So participants were significantly more efficient in the congruent condition than in the incongruent condition.

Looking for overall differences, do the two groups differ?

Next a t-test was performed to test the prediction that there is an difference between the control- and match-group's mean reaction time taken over all the measurements in time. We compared mean reaction times (RT) of the different time measurements between the control- and match-group (figure 7). There was no significant difference in the reaction times for the control- (M = 517.64, SD = 67.38) and match-group (M = 583.15, SD = 78.36); $t(8) = -1.98$, $p = .11$. So we did not observe an overall difference between the controls and match-group.

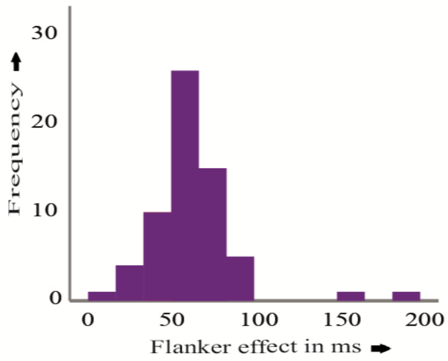

Figure 6: Histogram showing the frequency of the participants flanker effect. As can be seen there is a median of ±63 ms, *SD*= 26.63.

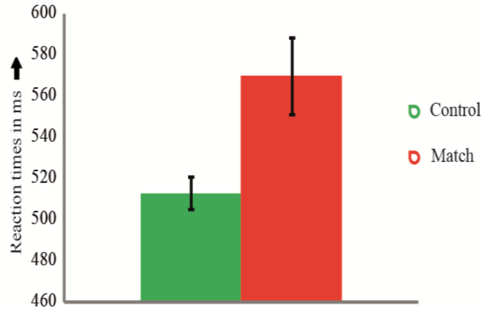

Figure 7: Overall RT of the control- (*M* = 517.64, *SD* = 67.38) and match-group (*M* = 583.15, *SD* = 78.36); *t*(8) = -1.98, p = 0.11.These results indicate that there is no significant difference between the mean RT taken over the different time measurements of the two group.

An independent t-test was then performed to see if there is a difference in efficiency in performance on the flanker task for the control- and match-group's mean reaction time taken over all the measurements in time. This efficiency measure was calculated by dividing the % correct responses by the RT in seconds[1]. No significant differences were found for efficiency between controls (*M* = 1.86, *SD* = 0.23) and the match-group (*M* =1.67, *SD* = 0.23); *t*(9) = 1.77, *p* = .11. So no significant differences in efficiency were found as a mean of the four measuring moments between the control- and match-group.

Checking for a learning effect

Then a one-way repeated measures analysis of variance (ANOVA) was performed to evaluate the null hypothesis that there was no change in the control participants' (*N* = 14) reaction time, flanker effect and efficiency when measured at day one (for the match group one week before their kickboxing match), day six (one day pre-match for match group) and day eight (one day post-match for the match group). This is done to only for the control group because of the shortage in data in the match-group, since only two out of six participants had done the one day pre-match trial.

For reaction time, the results for day one (*M* = 493.98, *SD* = 80.16), day six (*M* = 511.25, *SD* = 71.99) and day eight (*M* = 489.00, *SD* = 58.86) indicate no significant time effect. Wilkes' Lambda = .93, *F*(2 , 12) = 0.48, *p* = .63 , η^2 = 0.073. Thus there is no significant evidence to reject the null hypothesis, suggesting that there is no change in reaction over the three different moments.

For flanker effect, the results for day one (*M* = 54.66, *SD* = 21.79), day six (*M* = 51.94, *SD* = 15.69) and day eight (*M* = 63.88, *SD* = 13.45) again, do not show any significant differences. Wilkes' Lambda = .77, *F*(2, 14) = 2.133, *p* = .15, η^2 = 0.23. Thus there is no significant evidence to reject the null hypothesis, suggesting that there is no change in flanker effect over the three different moments.

For efficiency, the results for day one (*M* = 1.77, *SD* = 0.28), day six (*M* = 1.53, *SD* = 0.81) and day eight (*M* = 1.86, *SD* = 0.29) show no significant differences

[1] Formula for efficiency: $\% \frac{correct}{\frac{RT}{1000}}$

as a function of these time measurements. Wilkes' Lambda = .79, $F(2, 18) = 2.464$, $p = .11$, $\eta^2 = 0.22$. Thus there is no significant evidence to reject the null hypothesis, suggesting that there is no change in efficiency over the three different moments.

Neither reaction time, flanker effect nor efficiency yield any significant differences over these three measuring moments, so it can be stated that these participants did not experience a learning effect in their flanker task performance.

Comparing pre- and post-match performance

A two-way analysis of variance was conducted on the influence of two independent variables (group and time measurement) on their reaction time, flanker effect and efficiency. Group included two levels (control- and match-fighters) and time measurement consisted of two levels (day one and day eight). These time measurements were chosen for this test because of the shortage in data for the 3rd (day six) and the 4th measurement (one month post-match), since two out of the six match fighters did not do the one day pre-trial measurement.

No effects for reaction time (figure 8) were statistically significant at the .05 significance level except for the group factor. The main effect for group yielded an F ratio of $F(1, 36) = 9.353$, $p = 0.0042$, indicating a significant difference between control fighters ($M = 495.99$, $SD = 69.04$) and match fighters ($M = 583.48$, $SD = 104.64$). The main effect for time yielded an F ratio of $F(1, 36) = 0.11$, $p = .75$, indicating that the effect for the time was not significant, day one ($M = 524.24$, $SD = 96.85$) and day eight ($M = 520.24$, $SD = 84.30$). The interaction was not significant, $F(1, 36) = 0.218$, $p = .64$.

No effects for flanker effect (figure 9) were statistically significant at the .05 significance level except for the group factor. The main effect for group yielded an F ratio of $F(1, 36) = 4.55$, $p = .040$, indicating a significant difference between control fighters ($M = 57.01$, $SD = 18.33$) and match fighters ($M = 75.46$, $SD = 38.13$). The main effect for time yielded an F ratio of $F(1, 36) = 0.48$, $p = .49$, indicating that the effect for the time was not significant, day one ($M = 62.13$, $SD = 36.27$) and day eight ($M = 62.98$, $SD = 12.39$). The interaction was not significant but a trend can be seen, $F(1, 36) = 3.91$, $p = .056$ †.

No effects for efficiency (figure 10) were statistically significant at the .05 significance level except for the group factor. The main effect for group yielded an F

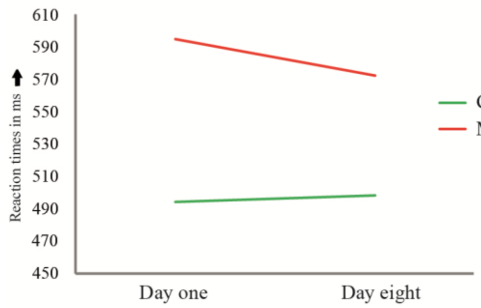

Figure 8: Reaction times of the control- and match-group on day one and eight. No significant effects were found between day one and eight, but the main effect for group yielded an F ratio of $F(1, 36) = 9.353$, $p = 0.0042$, indicating a significant difference between control fighters ($M = 495.99$, $SD = 69.04$) and match fighters ($M = 583.48$, $SD = 104.64$).

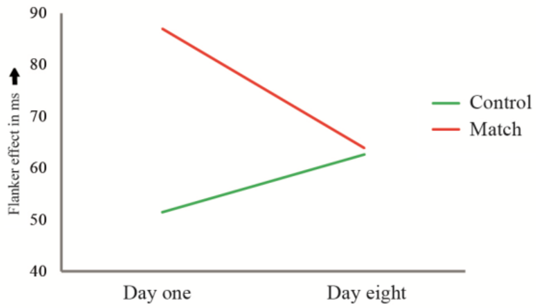

Figure 9: Flanker effect of the control- and match-group on day one and eight. No significant effects were found between day one and eight, but the main effect for group yielded an F ratio of $F(1, 36) = 4.55$, $p = .040$, indicating a significant difference between control fighters ($M = 57.01$, $SD = 18.33$) and match fighters ($M = 75.46$, $SD = 38.13$).

ratio of $F(1, 36) = 5.89$, $p = .020$, indicating a significant difference between control fighters ($M = 1.88$, $SD = 0.21$) and match fighters ($M = 1.66$, $SD = 0.36$). The main effect for time yielded an F ratio of $F(1, 36) = 1.20$, $p = .28$, indicating that the effect for the time was not significant, day one ($M = 1.77$, $SD = 0.28$) and day eight ($M = 1.86$, $SD = 0.29$). The interaction was not significant, $F(1, 36) = 0.082$, $p = .78$. These results indicate that there is no significant effect between the two measuring moments, but there is a significant between the two groups in both reaction time, flanker effect as well as in efficiency.

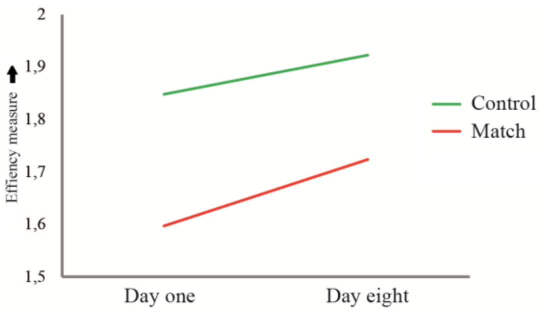

Figure 10: Efficiency of the control- and match-group on day one and eight. No significant effects were found between day one and eight, but The main effect for group yielded an F ratio of $F(1, 36) = 5.89$, $p = .020$, indicating a significant difference between control fighters ($M = 1.88$, $SD = 0.21$) and match fighters ($M = 1.66$, $SD = 0.36$).

Correlations of possible co-factors on reaction time and efficiency

To find factors that are influential in the performance of the flanker task, seven factors were correlated with reaction time. These correlations are calculated with 20 participants ($N = 20$) except for the factor which encompasses the total of hits a participant receives to the head during their match, these are based on three participants ($N = 3$). The factors include the Barratt's score ($r = .12$, $p = .60$), times of training per week ($r = .27$, $p = .24$), intensity of training ($r = .22$, $p = .35$), if the participant has ever been unconscious ($r = -.20$, $p = .41$), forgetfulness ($r = .42$, $p = .06$†), concentration ($r = -.085$, $p = .72$), quality of sleep ($r = .18$, $p = .45$), hunger ($r = .32$, $p = .17$) and total hits received to the head (r = .98, p = .022*).

Then correlations were done between efficiency and the Barratt's score ($r = -.092$, $p = .70$), times of training per week ($r = -.30$, $p = .20$), intensity of training ($r = -.066$, $p = .78$), if the participant has ever been unconscious ($r = .11$, $p = .64$), forgetfulness ($r = .36$, $p = .12$), concentration ($r = -.096$, $p = .69$), quality of sleep ($r = .24$, $p = .31$), hunger ($r = .35$, $p = .14$), and total hits received to the head (r = -.95, p = .050*).

No significant correlations were found except for a trend that was found between reaction time and forgetfulness (r = .42, $p = .06$ †) and a significant effect between total hits received to the head and reaction time (r = .98, p = .022*) and efficiency (r = -.95, p = .050*), as can be seen in table one,

Table 1: List of correlations, t-values and p-values of different possible influences on the flanker task performance on reaction time (RT) and efficiency (EF). These correlations are calculated with 20 participants (N = 20) except for the factor which encompasses the total of hits a participant receives to the head during their match, these are based on three participants (N = 3) No significant correlations were found, except for a trend that was found between forgetfulness and reaction time (r = .42, p = .06 †) and a significant effect between total hits received to the head and reaction time (r = .98, p = .022*) and efficiency (r = -.95, p = .050*).

	RT			**EF**		
	r	*t*	*p*	*r*	*t*	*p*
Barratt's score[1]	.12	0.54	.60	-.092	-0.39	.70
Times of training per week[1]	.27	1.21	.24	-.30	-1.33	.20
Intensity[1]	.22	0.97	.35	-.066	-0.28	.78
Ever been unconcious[1]	-.20	-0.85	.41	.11	0.48	.64
Forgetfulness[1]	.42	1.98	.06†	-.36	-1.63	.12
Concentration[1]	-.085	-0.36	.72	.096	0.41	.69
Quality of sleep[1]	-.18	-0.78	.45	.24	1.03	.31
Hunger[1]	-.32	-1.43	.17	.35	1.56	.14
Total hits received to the head[2]	.98	4.39	.022*	-.95	-3.18	.050*

[1] $N = 20$, [2] $N = 3$
† $p < .10$, * $p < .05$, ** $p < .01$, *** p <.0 .001

Discussion

Our expectations were that the control- and match group would have a similar baseline performance pre-match, and then performance would worsen as a result of the brain trauma sustained from the match for the match-group while the performance of the controls would stay stable (see fig. 1). Flanker effects would become greater and efficiency would decrease post-match. However our hypothesis that flanker task performance, especially the flanker effect, would worsen after receiving brain trauma from the kickboxing match has gathered no support from our results. Since there are no significant effects found between the different measurements in time, we can state that the match itself did not have an effect on the flanker effect and overall performance. However significant correlations were found between the amount of hits received during a fight and the reaction time and efficiency of the fighter on the flanker task. A positive correlation was found for reaction time and amount of hits received (r = .98, p = .022*), so more hits to the head would mean a longer reaction time. And since a negative correlation was found for efficiency and the amount of hits received (r = -.95, p = .050*), more hits would also mean a lower efficiency. These correlations fall in line with our expectations that more hits would mean a worse performance on these executive functioning tasks however it is important to keep in mind that these correlations are only based on three participants. Furthermore significant differences were found when the control- and match-group were compared.

Overall performance was significantly worse in the match-group on both reaction time, flanker performance as well as for efficiency.

These findings are not in line with the previous finding of Howel et al. (2013) where 20 participants were identified by specialized health professionals as suffering a concussion resulting from sport participation. These participants were matched with healthy control subjects. In their study the concussion group was significantly worse at an attentional network test with conflicting stimuli, as they had difficulty in ignoring surrounding irrelevant information. Even though we also find significant differences between our control- and match-group, they did not differ as a result of the sustained brain trauma of the match itself, as pre- and post-match trials yielded no significant differences. A possible explanation for these different findings might be that our match-group never actually received a concussion as a result of their match. Since Howel et al. (2013) had diagnosed their participants with a concussion via health professionals and in our study an assumption was made that the fighter would sustain brain trauma during their match.

There are several aspects of this experiments' set up that can cause doubt in its reliability. As there is a low statistical power in this experiment which is due to the shortage in test subjects. This shortage is the result of many factors that encompass the kickboxing community. For starters it is important to keep recent events surrounding research on kickboxing-related brain injuries in mind. Since these findings suggest that kickboxing leads to a greater risk of developing brain disease like, among others, neuroendocrine abnormalities such as hypopituitarism (Tanriverdi & Kelestimur, 2015). Kickboxing gyms have been in the spotlight of the media giving them a bad reputation, making the trainers as well as the fighters much less receptive to all kinds of experiments surrounding their sport. This may be causing an unwillingness to cooperate, as 5 out of 14 match fighters and 27 out of 40 controles never responded after participation had been promised. So it can be stated that compliance amongst the kickboxing community is low with respect to brain related research. In addition, there are a lot of facets that may influence the continuation of a kickboxing match. For instance a match can be canceled because of an injury, a fighter is not in the same weight class, one of the fighters not showing up etc. This caused 3 of the 14 match fighters to drop out.

Moreover because the task is web based, there is little to no supervision possible regarding the surroundings and timing in which the participant engages in the flanker task. Nor can we be sure that the participants are actually who they say they are (e.g. one of the participants' sister did the flanker task under his name). Also the freedom to do the task whenever the participant has spare time has caused great irregularities in the timing that the participants were doing the task. As some did the task in the morning, some in the evening and there was even one participant who did the task at 3 a.m. making his results questionable as sleep deprivation has an effect on flanker task performance according to Tsai et al. (2005). Furthermore because of the limited ways to get participants to do the task, only two out of the six match fighters have done the one day pre-match measurement which would have been important to measure the learning effect of the flanker task had there been an effect in the control-group between the measurements. Then the learning effect could have been incorporated in the one day post-match measurement for these participants, possibly countering the effect of the match itself.

Furthermore, we are trying to quantify head injury in a relatively precise manner. It is important to know the participant's history with regard to previous occurrences surrounding head injury. Because of the small amount of participants there is little statistical power for the analysis to correlate several covariates (e.g. Barratt's score, how many times they train per week, intensity of previous match/training etc.) to the performance of the flanker task. This makes it difficult to quantify the exact influence of the match, because it is unknown in how the control group and the match group differ amongst one another. Since 12 out of 15 controls have already been in kickboxing matches, and several of them have not answered questions regarding these matches, it is hard to see where the baseline difference between the controls and match group is coming from.

The current way of ranking the amount of impact taken during a kickboxing match is relatively inaccurate. Although it is more accurate than the ranking done by the judges of the match itself (the ones determining who wins or loses) since we videotape it and count the amount of hits to the head, for our purposes it is still too much of a rudimentary way to measure the impact a fighter receives. For future studies it is desirable to use a way to measure the forces affecting the fighters brain. There are already several ways to manage this, like a helmet equipped with force sensors or using developments in creating a mouth guard that measures translational forces with six degrees of freedom (Camarillo et al, 2013), whereas older models only use three degrees of freedom, up/down, left/right, front/back. This would make quantifying impact much easier and more precise.

It is possible that with a greater test battery and a complete dataset, the possibly intertwined effect of the learning effect and match effect can be unraveled. Although the need for this is open for discussion after these results, as it suggests that match fighting has no effect on flanker performance. However since the match group does have a significant baseline difference and can possibly have an effect on the long run. So it might be of interest to monitor kickboxers in a longitudinal manner as they progress in the kickboxing world. Since the pre- and post-match results are not significantly different from one another, a model quantifying the severity of a concussion seems far out of reach. So a functional way to quantify concussions has yet to be found for our athletes. At least kickboxers can have a good night's rest knowing that they can still perform equally on an Eriksen flanker task based camel race after a fight!

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