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REACTION TIMES IN A FIELD EXPERIMENT: IS REALLY ALL ABOUT INSTINCTIVENESS?

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Reaction Times in a Field Experiment: Is Really All about Instinctiveness?

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Abstract

Several papers in experimental economics use reaction times (RTs) to assess whether a decision is instinctive or not. This paper analyses a field experiment (the behaviour of athletes at the World Swimming Championships) in three steps, where only the (expected) payoff changes (i.e. increases) from one step to the next. The payoff depends on the time of the race, of which the RT is part. Considering, for each competition, a homogeneous sample of swimmers, the paper shows that RTs decrease as the expected payoff increase. The observed reductions are comparable in magnitude to those observed in other experiments, where conscious/cognitive process are induced (or, at least, present). The paper concludes claiming that a share of the observed RTs is determined through a cognitive process, and therefore RTs are not pure measures of instinctiveness.

Keywords: reaction times, experiment, instinctiveness, cognitive processes

JEL codes: C93, D03

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1. Introduction

Several economists consider reaction times (RTs) of individuals as relevant characteristics of the individual decision processes (Rubinstein, 2007 and 2012) . The idea that RTs provide insights into the process of deliberation prior to making a decision is very old in the psychological literature and, according to Stenberg (1969), dates back to 1868. RT is generally defined as the time elapsing since a stimulus is received by the individual to when s/he responds to that stimulus. RTs have been taken as a measure of how much the response is instinctive; in particular, the shorter the RT (i.e. the faster the response to the stimulus), the more instinctive the (mental) process that led to the response (Rubinstein, 2007 and 2008). In Rubinstein's words: "choices that require more cognitive activity will result in longer response times than choices which involve an instinctive response."[1] In other terms: where subjects play a strategic game, they can use strategies that belong to two different sets: instinctive and cognitive (Kahneman, 2011). Choosing a strategy from the former set requires less time than choosing one from the latter, since a cognitive process takes longer time than an instinctive reaction. Consistently with this interpretation, Brown et al. (2008) find that RTs are increasing with task difficulty[2], but decrease as the subject becomes familiar with the game and, after some rounds[3], tend to stabilise around a fix level. Gabaix et al. (2006) find similar results: RTs are longer when people have to choose between similar rather than different alternatives. The proposed interpretation of RTs seems therefore consistent, even if reasoning leads sometimes to a higher payoff than instinct (Arad and Rubinstein, 2012) and sometimes to the opposite result (Piovesan and Wengström, 2009).

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[1] Rubinstein (2007), p. 1245.
[2] See also McEwan (1939).
[3] On the reduction of RTs as the subjects familiarize with the game see also Piovesan and Wengström (2009).

Sommer et al. (1990) Jentzsch and Sommer (2002) have already shown that, when an event is expected, the RT is shorter than when the event is expected. This is not surprising, and already shows that cognitive processes (in this case, expectations) can influence RTs. The present paper takes a step more, investigating whether RTs can be affected by variations in the payoff of an action. This is of particular interest for economics, since RT is determinant for maximising the payoff in several cases (auctions, trade in the financial markets, skill tests, etc.). For the purpose of this study I use a multi-stage game, where RTs contribute to determine the final ranking (and the payoffs) of the participants. Moreover, at each stage of the game the payoff is increased, while all the other characteristics of the game frame remain unchanged.

The literature cited so far considers two types of RTs. Rubinstein (2007 and 2008) refers to the time elapsing between when an individual is presented a problem and when s/he responds to it (for example the time between a question and the answer). The other type of RTs is the time between some stimulus (for example a sound) and the beginning of the reaction to that stimulus. The RTs of type 1 include (usually) some cognitive process, while the RTs of type 2 are generally considered instinctive. Here I claim that also RTs of type 2 are partially the consequence of a cognitive reasoning and, therefore, the distinction between the two types is only apparent.

The extant literature considers most games where the payoff does not depend on how quick the subject responds to the stimulus, and therefore the deciders are not under the pressure of time. Several games used in game theory and economics are of this kind: the prisoner's dilemma, the ultimatum, the dictator and the public goods games (Camerer, 2003) are examples such category. There are other games, however, in which RTs contribute to determine the payoff. Examples of these are the Dutch auctions, and the financial trading. Here the timing of the decision, and therefore the RT to the stimulus (changes the price of the item/security) are crucial for the agent's payoff. In particular, the fastest agent is the one who secure the auctioned item or the traded security. Although this is not synonymous of maximizing the payoff (winner's curse in Dutch auctions), who comes late gets nothing or may have to buy at a price different from his best choice.

Following Rubinstein's (2001) argumentation that experiments should test economists' assumptions rather than their conclusions, this paper challenges the current assumption of experimental economists that cognitive reasoning always results in a longer RT than instinctive reactions. However, in all the games analysed in Rubinstein (2001) the RT does not concur to determine the payoff. Nonetheless, there may be other games, in which RTs are part of the performance that determines the final payoff[4]. In this paper, I claim that if the subjects' payoff depends on their RTs positively, then this influences the RTs to maximize the payoff.

In particular, people will try to minimize the RT, and this minimization is likely to result from a cognitive (although perhaps unconscious) process. To test this hypothesis, I analyse the reaction times of swimmers disputing long-course World Championships. This is a natural framework, in which the subjects are not aware to be part of an experiment (actually they are not) and have strong incentives to behave "honestly" (after all, they have trained for a large part of their life to get there and dispute that gold medal!). Moreover, they are (self) selected in such a way to constitute a homogeneous group (same motivation, same goal, same training, same rules, same environment, and same incentives). The final time in a swimming race is the sum of two components: the RT and the time of the swim; *a priori* these can be classified as instinctive (the

[4] An example is that of Dutch auctions, where a sort of clock proposes descending prices for the auctioned item, until one of the participants stops the clock and buys the item at the price indicated by the needle. Let suppose that at any given price more than one agent is interested in buying the item, and let suppose also that each participant attaches to the item a different value. This means that at any given price proposed, each agent has a net profit and that as the price proposed by the clock decreases, each of these net profits increases. Now, let consider two people with positive, but different net profits for a given price; if the RT is decreasing in the payoff, the winner of the auction will be the person with the highest payoff.

RT) and cognitive (the time of the swim). The reason is that the swimmers calibrate their effort during the swim, observing what the competitors are doing; in this sense, the time of the swim is the result of a cognitive process. Instead, the RT is (should be) the instinctive response to the starter's signal, and should not involve any cognitive process. RTs in swimming are part of the total time that determines the final ranking, however their relative contribution to (and therefore their importance for) the total time decreases as the length of the race increases. Therefore, for example, the difference between the minimum and maximum RTs in the freestyle 100m finals is 0.21s, while the average difference between the gold and the silver medals for the same distance is 0.19s. This means that there are cases in which shorter RTs can modify the result of the competition. This is true for the short races, while is not for the long, where the difference between the first swimmers in the ranking are much larger than in short-race competitions. In conclusion, RTs are relevant only for athletes who contend in short races. Therefore, if the prize is an incentive for the swimmers to shorten their reaction times, this should be observed more in the short than in the long races.

2. Data and methodology

The analysis is based on the results of FINA long-course World Championships from 2003 to 2011. These are held every two years and only top-athletes are selected to participate. Although they are of different ages, they all have trained for years and have taken part in several top competitions; therefore, they are used to react to starting signals. All the results are released publicly and freely on the FINA's website after each championship, since 2003. For each stage (heats, semi-finals – where provided by the rules – and finals) of each competition, the Federation discloses names and ages of the participating swimmers, reaction times, final times and rank, and intermediate times (at every 50 meters turn). Reaction times displayed in the federal official releases represent the time elapsing from the starting signal to when the swimmer's feet leave the block (Lyttle and Benjanuvatra, 2004).

Swimming competitions are particularly suitable for the analysis conducted in this paper. Let now consider their structure: I will stress that, moving from a stage to the next, the payoff increases, while all the other aspects remain constant. Winning the gold medal requires to qualify for semi-finals first and for the final then. In the first stage (heats) the swimmers compete to secure one of the two semi-finals; this means that one must rank at least sixteenth after the heats. To dispute the final, an athlete must rank at least eighth at the end of the two semi-finals. The rule of distribution of the swimmers between the heats and between the lanes depends on their qualification time. This means that each swimmer competes against athletes of similar ability, and thus the individual performance should not be affected by different abilities of the competitors between the stages. Furthermore, the final ranking after each stage includes all the athletes who disputed that stage, it is based only on the final time of each swimmer, and does not depend on the position of the swimmer in the rank of his/her heat or semi-final. These rules ensure constancy of incentives at each stage and that each swimmer observes directly[5] contestants of similar ability through all the stages of the competition, and therefore the way in which the swimmers are sorted in the heats and in the semi-finals does not affect strategies and performances through the stages.

According to the federal swimming rules, all the member national federations can enrol at most two athletes for each race; these first run the heats. Then, for short races (i.e. 50, 100 and 200 meters) the best sixteen swimmers at that stage gain access to the two semi-finals[6]; athletes

[5] Each swimmer observes the seven competitors s/he is in the poos with.

[6] The regular swimming pool for competitions is divided into eight lanes.

swimming long races (400, 800 and 1,500 meters) access finals directly after the heats. Eventually the eight best semi-finalists (for short races) or the eight best performers in the heats (for long races) contend for the gold medal.

The swimmers are allocated to the eight lanes of the pool according to their times in the previous step (in the case of semi-finals and finals), or to the time in the qualification trials for accessing the Championships (in the case of heats). The rule prescribes that the athlete with the best qualification time swims in lane 4, the second in lane 5, the third in line 3, the fourth in line 6, the fifth in lane 2 and so on. This means that the swimmers are allocated to lanes following a deterministic rule. Assuming that the best athletes have faster reaction times[7], the process of allocation may engender some bias in what observed. For this reason, I rendered the samples analysed comparable, by considering, for each race, only the average RT of the eight finalists. In such a way, the reaction times of the eight finalist swimmers are considered. A possible different approach is to consider the reaction times of the eight best swimmers in each race. However, given also the high and positive correlation between the sample of the eight finalists and that of the eight best swimmers in heats and semi-finals, the results do not change[8]. A further problem is the interdependence between the observations in each race. It is likely to assume that the athletes react to both the auditive stimulus of the starter and to the visual stimulus of the other swimmers' reaction. In other words, it is likely that the swimmers who wait for starting the race on the blocks react also to the movements of the first to start, and this engender interdependence between the

[7] This is actually the case: especially in short races, the time differences at the end of the race may be smaller than the differences in reaction times between athletes. Hence, a swimmer may end first and another second just because the first was faster to react than the second was. In other words, the placement in the final rank depends also on the reaction time. Consequently, considering only the fastest eight swimmers reduce biases that may arise from different starting techniques, or different abilities to react.

[8] For brevity sake, the results for this sampling approach are not shown, but they are available upon request.

observations in a given race. However, the use of the average RT of the eight finalists for each stage solves the problem of interdependence.

At this point, the means so calculated can be compared. In particular, for short races six comparisons are possible: across distances RT in each stage (heats, semi-finals and finals) are compared considering two consecutive distances in a time (i.e. 50m vs. 100m; 100m vs. 200m); then for each distance RT in heats vs. RT in semi-finales, RT in semi-finals vs. RT in finals and RT in heats vs. RT in finals. For long races, the same comparisons are performed, except for those involving semi-finals (that are not provided for these distances). The first set of comparisons allows analysing how reaction times change as the race distance varies (and therefore the value of an early reaction decreases); the second set shows the variations in RTs when the highest payoff increases going from qualification for the next stage to the gold medal. However, differences detected between different distances may be simply due to different trainings and approaches to the specific competition; in other words, since the value of a short RT decreases with the swimming distance, in their preparation the athletes who train for short races may focus more on RTs than the athletes who train for long races. This should not be the case when a given distance is considered, as the value of a short RT is constant across all the stages of the competition. Therefore, the comparisons between stages of a same competition are more robust and more informative than those between distances.

Reaction times decrease with practice and training (Blanksby et al., 2002), however any difference in this respect between subjects disappears when they all constantly train (see for example Räty et al., 2002). For this reason, I selected only top athletes, and checked whether the RTs are different between different age groups (assuming that older swimmers have been training for more years). The correlation between age and RT is always extremely low (never larger than -

7%) and never significant, witnessing that at the level of world championships, the training is no longer able to improve the RT of the swimmers, and therefore differences in age between the athletes do not matter in the present analysis[9].

3. Results

The results are presented in three tables: the first (Table 1) compares the average RTs between different distances for a given step (heats, semi-finals, finals) of a competition across distances; the second (Table 2) reports the RTs between the different steps of a competition for a given distance. The third (Table 3), eventually, is the same as the first table, but displays the RTs of the swimmers who did not access the final step.

Table 1 shows that the RTs grow with the distance to swim, that is as the share of the RT in the total time of the race shrinks more and more. However, this might just be due to different trainings: since RT is not important over long distances, then the athletes who run these distances do not work on reducing their RTs, in contrast with the swimmers who train to swim short distances, for which the RT represents a relevant share of the total final time.

Table 2 compares the RTs between the different steps of a competition for a given distance. Here the figures show that the average RT decreases significantly from heats to semi-finales and from these to finals for almost all the distances swam. This suggests the existence of some psychological mechanism that renders the athletes quicker to react to the starter's signal, as the prize of the race increases from just qualification to the gold medal. The result is interesting, as it reveals that, while RTs may well be a measure of how instinctive a response is, they appear to be influenced by the frame of the game. In other words, when the RT concurs to determine the

[9] Should the opposite have held, the presence of very young swimmers in some competitions may have biased the results.

payoff, then the individual is able to influence it voluntarily. RTs seem to have two components: one strictly instinctive and another cognitive. Given the small reductions observed in RTs, the first component appears much larger than the second does. However, the reduction due to the psychological component is big enough to be of some value for the athletes who swim short distances.

It is also noteworthy that the gains in RTs are on average very small, although sufficient, to modify the final ranking in some cases. For example, considering 100m competitions, in 16.8% of cases the average reduction in the RT between heats and finals (which is about 1.5 hundredth of second) is larger than the time difference between the gold and the silver medal. That figure reduces to just 5% if the competitions over 200m are considered, and converges to 0 for all the longer distances. Nevertheless, the RTs decrease significantly in all the competitions, but 800m freestyle, considered here. This suggests that the idea that “the faster the better” prevails on other rational considerations about the actual value of the reduction in the RT. A possible reason why the reductions in RTs are as small as observed is that the swimmers may be risk averse. Leaving the starting block twice before the signal entails disqualification, therefore the willingness to reduce the RTs may be compensated by the worry of disqualification, thus resulting in small reductions in the RTs[10]. Nevertheless, the value of the prize is larger in finals than in heats and semi-finals; as a consequence the athletes may also become more prone to take risks in finals than in the other stages of the competition. In other words, the shorter RTs in finales may result from a cognitive process that induces the swimmers to accept higher levels of risks, given the higher remuneration of winning a final than any other stage. Analogously, investors are ready to buy risky securities that pay high returns. That the reduction of risk aversion is cognitive is shown by the

[10] This is consistent with Rubinstein (2012), who often finds a negative correlation between the RT and the probability of making a mistake, when the notion of a mistake is a clear cut.

absence of any statistically significant reduction in RTs in long-run swimming competitions. There the athletes know that, differently than in the case of short-run competitions, any small gain at the start will have no effect on the final ranking. As a consequence, the swimmers are not ready to take more risk, what reflects in RTs that do not decrease between heats and finals.

Consider now the cognitive component of the total time. This is not interesting *per se*, as this time does not represent the time of a cognitive process, but rather it is the result of this process. However its variations are the consequences of a cognitive process, either because the swimmers put more effort in the final than in the heat (since the competition is for the medals and not just for qualifying), either because at least one put more effort and the others emulate that one or because of both. The data do not allow for choosing between these possible interpretations; however, all these possibilities are not mutually exclusive and do not change the interpretation of the results.

Let now consider another interesting variable, which supports the cognitive interpretation of the reduction in the RTs. Table 3 presents the average percentage decrease in the swim time and in the RTs between a stage of the competition and the previous. Given that, while swimming in the pool, the athletes calibrate their effort considering the performance of the competitors and the goal of the race (i.e. qualification or medal), and given that swimming faster entails more effort, then the reductions in total time likely result from a cognitive rather than from an instinctive process. A main observation emerges: the order of magnitude of the reductions in RTs and total times is the same: around (or less than) one percentage point. Jentzsch and Sommer (2002) obtain an average reduction in RTs between 0.68% and 1.03%[11], when cognitive processes

[11] Jentzsch and Sommer (2002) propose two experimental treatments; the reductions in the RTs are different, depending on which treatment is considered.

are activated by passing from unexpected to expected stimuli. This figure is consistent with those found in the analysis presented in this paper; it is noteworthy that cognitive processes (that induced in Jentzsch and Sommer's paper and that induced during the swim competition) lead to time reductions, which are very close to that detected in the swimmers' RTs. This similarity supports the interpretation that the reductions in the swimmers' RTs are the consequence of a cognitive process, rather than of some other instinctive mechanism. Now, the only change in the framework between the different stages of a swimming competition is the value of the individual position in the final ranking (qualification in the case of heats and semi-finals and medals in the case of finals). Therefore, it can be argued that the conscious process that leads to the observed reductions in RTs is led by the increase in the payoff at each stage of the competition.

Last but not least, I would discuss a problem highlighted in section 2: swimmers may react to the movement of some other contestant. This reaction, of course, would not be cognitive, but instinctive. Let start by assuming that all the swimmers but the first-to-move react only to the movement of this latter. The results presented here would in any case suggest that the first swimmer to move reacts in shorter times as the final approaches. This would allow for concluding that the cognitive process, which induces the reduction in the RT of the first-to-move, is responsible of the reduction in the RTs of all the other contestants. In other words, although indirectly, the observed reduction in all the RTs would be anyway determined (also) by a cognitive process. However, if the reaction to the optical stimulus generated by the first-to-move were the only (or the main) explanation, then we should observe several swimmers to dive in response to a false start. Anecdotal evidence, however, generally suggests the opposite: the swimmers perceive false starts as such and do not leave the starting block[12]. In other words, the visual reaction component, if any, seems to play a minor role in determining RTs. This supports the interpretation of the observed reduction in RTs in terms of a cognitive rather than an instinctive process.

4. Discussion and conclusion

The aim of this paper is neither that of criticising the extant works based on RTs, nor to suggest that their conclusions are not valid. Rather, this paper aims at warning economists about the use of RT as an indicator of pure instinctiveness. In particular, what I wish to stress is that RTs seem to present two components: one instinctive and the other resulting from some conscious (say cognitive) process. The former part is much greater than the latter, at least in the framework considered in this paper (even if other authors found results of similar magnitude). There may be of course other cases, in which the cognitive process activated by the situation leads to an increase in the RTs of the subjects. This will then depend on which action (i.e. a reduction or an increase in RTs) maximises the payoff for the individual.

One might argue that the results of this paper are relevant only when RTs are directly involved in determining the payoff. However, Rubinstein (2007 and 2012) shows that, in several cases, error rates in completing tasks correlate significantly with RTs, also in settings, where the payoff is independent of the time taken to complete the task. Therefore, also in these contexts, an increase in the (expected) payoff may induce the subjects to take more time for thinking before taking a decision. The data available so far do not allow for testing this hypothesis, which is left, then, for further research.

[12] See for example the final of the freestyle 1,500 m. at the Olympic Games in London, 2012, or Labeid's false start at the 2011 World Swimming Championships. In both cases only one swimmer dives, while all the others remain on the starting blocks.

The results presented in the paper do not hinder the use of RTs as a measure of the instinctiveness of a response. They only show that RTs are sensitive to the payoff of the game and are slightly modified in order to maximise the probability of getting the highest payoff. Apparently consciousness has only a small (tough relevant) effect on RTs; therefore large differences between RTs may still indicate that some decisions involve more cognitive processes than others do.

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Table 1. Comparison of RTs between competitions over different distances at a given stage (hundredths of second).

	Heats													
	50 metres	100 metres		100 metres	200 metres		200 metres	400 metres		400 metres	800metres		800 metres	1500 metres
	72.48	73.71		73.71	75.85		75.85	79.43		79.43	82.79		82.79	84.06
Significance	**			***			***			***			-	
	Semi-finals													
	50 metres	100 metres		100 metres	200 metres		200 metres	400 metres		400 metres	800metres		800 metres	1500 metres
	71.98	72.96		72.96	75.36									
Significance	-			***										
	Finals													
	50 metres	100 metres		100 metres	200 metres		200 metres	400 metres		400 metres	800metres		800 metres	1500 metres
	70.83	72.18		72.18	74.49		74.49	78.97		78.97	82.59		82.59	82.33
Significance	*			***			***			***			-	

Levels of significance: *90%; ** 95%; *** 99%.

Table 2. Comparison of RTs between the different stages of competitions over a given distance (hundredths of second)

		50 metres				100 metres				200 metres	
	Heats	Semi-final	Final		Heats	Semi-final	Final		Heats	Semi-final	Final
	72.26	71.98	70.83		73.42	72.44	72.10		75.57	74.83	74.49
	***				***				***		
		***				**				**	
		400 metres				800 metres				1500 metres	
	Heats	Final			Heats	Final			Heats	Final	
	79.43	78.97			82.79	82.59			83.39	82.39	
	***				-				***		

Levels of significance: *90%; ** 95%; *** 99%.

Table 3. Reductions in total and reaction times from a stage to another of competitions, over a given distance (percentage figures).

Distance	Semi-final - heat	Final - semi-final	Final - heat
Total times			
50 mts	-0.72	-0.16	-0.88
100 mts	-0.72	-0.21	-0.93
200 mts	-0.85	-0.22	-1.07
400 mts			-0.44
800 mts			-0.42
1,500 mts			-0.47
Reaction times			
	Semi-final - heat	Final - semi-final	Final - heat
50 mts	-0.39	-1.60	-1.99
100 mts	-1.33	-0.47	-1.80
200 mts	-0.98	-0.45	-1.43
400 mts			-0.58
800 mts			-0.24
1,500 mts			-1.20