The relationship between play behavior and decisional impulsivity

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Abstract

The possibility to play in the juvenile and adolescent phase of animals and humans is crucial for a normal maturation- and development process to adulthood. Play deprivation may result in aberrant behavior or even psychical problems, accompanied with impaired cognitive control over behavior and enhanced impulsivity. To investigate the correlation between play behavior and impulse control, rats were categorized in subgroups of high-, medium- and low players based on their tendency to play in weeks 4 and 5 after birth. A recent study showed no correlation between play behavior and impulsive actions in the five-choice serial reaction time task (5-CSRTT). The aim of this study is to determine whether individual differences in social play behavior are related to impulsive choice behavior, using the delayed reward test. In the delayed reward test the rats have to choose between an immediate small reward or a delayed large reward, whereby the delay increases within and between sessions. The test is divided over 4 phases. In each phase the delay increases within a session to 12, 24, 48 and 60 seconds. When an individual chooses the smaller immediate reward over the large delayed reward as delays are increasing in duration, this can be considered to reflect augmented impulsive choice behavior. After analyzing the data of this study, the results show no significant difference between the low-, medium- and high players in the preference for the large reward depended on the duration of the delay. In conclusion, according to this study there is no direct relation between play behavior in the juvenile and early adolescent stages of rats and decisional impulsivity.

Key words

Play behavior, impulsivity, decision making, impulsive choice, control over behavior, play deprivation

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Introduction

Social play behavior and play behavior in general is crucial for neural- and behavioral development. Play behavior is necessary for adaptation to unexpected situations or altering surroundings, and therefore is of importance to the well-being of an individual (Pellis and Pellis, 2013). In addition, play is highly rewarding and has a positive effect on the physical condition. For example, play reduces the glucocorticoid stress-response to unexpected situations and play was proposed to have a positive influence on the immunocompetence. Moreover, improved thermoregulation was described in animals that have played more compared with animals that played less (Spinka, 2001). During play bouts, the situation changes fast and unexpected situations arise. Therefore, an individual has to use cognitive skills to put the situation in perspective and adapt to the new situation. The possibility to play during development has been shown to be of importance for the development of cognitive control over behavior and result in less impulsive actions (Baarendse et al., 2013). Elevated level of impulsivity is often seen in psychiatric disorders including ADHD, addiction and personality disorders (Pattij and Vanderschuren, 2008). Moreover, the candidate genes responsible for the deficits in impulse control are related to the candidate genes important in alcohol addiction (Kreek et al., 2005). This suggests that impaired cognitive control, and therefore more impulsive behavior, may also be an underlying cause in developing alcohol addiction. The elevated levels of impulsivity that for instance are seen in these disorders, is thought to be caused by changes in the serotonin-, dopamine-, noradrenaline-, glutamate- and cannabinoid neurotransmission activity (Pattij and Vanderschuren, 2008; Baarendse and Vanderschuren, 2011). These neurochemical abnormalities, including disrupted synaptic plasticity, are also seen in animals that were socially isolated during their development (Fone and Porkess, 2008). The neural maturation process takes place during the juvenile and adolescent stages of life when play is abundant. Social isolation and play deprivation in this critical period in life may

cause deficits in this neural development. Moreover, play deprivation is associated to impaired cognitive control and enhanced impulsive behavior and may result in aberrant behavior or even psychological problems (Baarendse et al., 2013). An example of psychological problems that have been associated with aberrant social behavior is substance use disorder, including alcohol addiction, which in turn has been linked to poor cognitive control (Baarendse et al., 2013).

Impulsivity

Impulsivity is characterized by diminished inhibition and is a necessary component of natural behavior of animals and humans that might help individuals to adapt to changing situations (Pattij and Vanderschuren, 2008). However, impulsivity may not always be functional. According to Dickman, dysfunctional impulsivity can be described as acting without forethought, but functional impulsivity can be described as acting with little forethought when the situation is optimal (Dickman 1990), or acting suddenly in an unplanned manner to satisfy a desire (Kreek et al, 2005). The behavioral expression of impulsivity can vary and is categorized in 2 types of impulsivity: impulsive choice and impulsive action. Impulsive action is also termed motor impulsivity and reflects difficulties in the ability to inhibit actions. By contrast, impulsive choice is decisional impulsivity that for example is reflected by aversion for delay and the preference for a faster but smaller reward (Pattij and Vanderschuren, 2008). Different kinds of tests are used to study these types of impulsivity in animals. Impulsive action is often examined with the 'stop signal reaction time test' (SSRT) and the '5-choice serial reaction time test' (CSRTT), in which the rats tend to make more premature responses when they have to wait until a visual stimulus is shown before they get a reward. The amount of premature responses is a well-established parameter for the impulsive actions. Impulsive choice can be assessed using a so-called 'delayed reward test' (DRT), in which the rats have to choose between an immediate small reward or a delayed large reward, whereby the delay can be increased within or between sessions (Dalley and Robbins, 2017). When an individual chooses the smaller immediate reward over the delayed reward as delays are increasing in duration, this can be considered to reflect augmented impulsive choice behavior (Ainslie, 1975).

Impulsivity is mediated by prefrontal cortical, striatal and limbic brain regions. Interestingly, impulsive choice and impulsive action are mediated by different neurobiological processes and regulated by different brain regions. The limbic regions are primarily most important in the impulsive choice processes (Cardinal et al., 2001, Winstanley et al., 2004a, Cheung and Cardinal, 2005). At the neuropharmacological level, especially dopamine neurotransmission is considered to be important for delay aversion processes. Interestingly, whereas enhanced dopamine neurotransmission (in the orbitofrontal cortex) reduces impulsive choice, enhanced dopamine neurotransmission (in the nucleus accumbens) increases impulsive action (Baarendse and Vanderschuren, 2012). As mentioned in the introduction, these neurochemical abnormalities in impulse control including also the serotonin-, noradrenaline-, glutamate- and cannabinoid neurotransmission. The alterations in the neurotransmitter system responsible for decisional impulsivity are thus not only describable to one system, but the interactions between the different neurotransmitter systems are important in the impulsive choice making (Pattij and Vanderschuren, 2008).

Aim of the study

In past studies at the department of Animals in Science and Society, it was shown that depriving animals from social play at young age increases the risk for additive behavior with enhanced levels of alcohol consumption in their adulthood (Lesscher et al. 2015). Moreover, high playing animals were shown to consume more alcohol than adults, but at the same time have more control over their alcohol consumption. These findings confirm that the possibility and tendency to play during development are critical for adult

functioning that may reflect altered cognitive control. Further research is necessary to determine the reason why high players have more control over their alcohol consumption, which may involve augmented cognitive control. The aim of this study is to determine whether individual differences in social play behavior are related to impulsive choice behavior. We hypothesized that high playing rats may be less impulsive compared to low playing animals. This hypothesis was partly tested in a previous experiment using the '5-choice serial reaction time test' (CSRTT) to test the motor impulsivity. The results of this experiment suggested that the amount of play behavior and motivation for play is not related to impulsive action making. In the current study we compare high-, medium- and low playing rats for impulsive choice, using the delayed reward task.

Materials and methods

Animals

36 male Lister Hooded rats (Charles River, Sulzfeld, Germany) were already characterized for play behavior at the onset of this research project. They were categorized in subgroups of high-, medium- and low players based on their tendency to play (number of pins and pounces) in weeks 4 and 5 after birth. The animals that were used for this experiment were derived from two separate batches. The first batch was older than the second one and was therefore higher in weight. They were housed individually under reversed lighting conditions (lights on from 19.00 to 07.00 h). At the beginning of the experiment the first batch of twenty rats weighed 470-625 gram and the second batch of sixteen rats weighed 300-350 gram. The rats were placed on a restricted diet of 4 g of standard rat chow per 100 g bodyweight per day. The first training weeks some rats received more chow when they were losing weight. They received the chow after the training- and testing sessions. The weights were monitored two times a week. For an overview of the average weights between batch 1 and batch 2 over the weeks see figure 1. All experiments were approved by the Animal Ethics Committee of Utrecht University and were conducted in agreement with Dutch laws (Wet op de Dierproeven, 1996) and European regulations (Guideline 86/609/EEC).

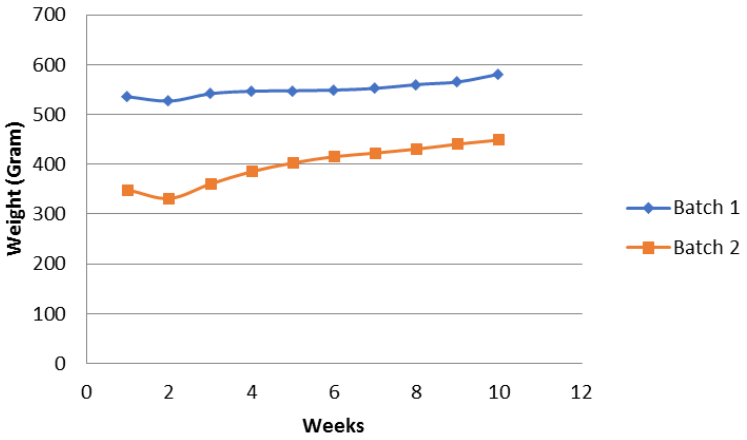


Figure 1. Weight of the animals over the weeks of the experiment

Apparatus

Training and testing was conducted in 8 operant conditioning chambers (30.5×24×21 cm; Med Associates, St. Albans, VT, USA) that were positioned in sound-attenuated boxes, equipped with a fan for ventilation, to mask extraneous noises. The boxes were illuminated by a white house light. Each box was equipped with a curved wall with 5 nose-poke holes with an infrared detector and a yellow stimulus light. Only the middle 3

nose poke holes were used for training and testing in this study. Food pellets were delivered in the opposite wall via a dispenser. Experimental events and data collection were controlled using MED-PC software for windows.

Behavioral procedures

Training

At the beginning of the experiment the rats were trained to make a nose poke response to get a reward. Therefore they were exposed to the operant chambers for 30 minutes or 100 trials whereby a stimulus light in one of the holes was on for 30 seconds in the first phase, for 20 seconds in the second phase and only 10 seconds in the third shaping phase. Between the trials (inter-trial-interval) there were 2 seconds in the first and second phase and 5 seconds in the third phase. The rats progressed to the next phase when they made 30 correct responses in a session. A response was scored as correct response when the animal reacts on the stimulus light and poked their nose in this hole within the time the light was on. They got a reward at the other site of the box. The premature responses, omissions and incorrect responses were also scored but not added as correct response. In the last phase the rats had to make 50 correct responses in a session to continue to the DRT training. In the DRT training, the rats first had to make a nose poke in the middle hole. This results in the illumination of the light in the two adjacent stimulus holes. Nose poking into one hole resulted in a small reward (one food pellet) and nose poking in the other hole resulted in a larger reward (four food pellets). They pass this phase when they made more than 80 percent correct responses. After the DRT training phase, the rats started with two forced trial sessions before they started the actual delayed reward tests. In these forced trial sessions either one hole with the small reward was illuminated or the other hole with the large reward, but not both. The rats were trained 5 times a week for 10 weeks, with one session a day during the dark phase (7.00-19.00).

Delayed reward testing

In the delayed reward test the rats had to choose between an immediate small reward or a delayed large reward. The delayed reward task started when the animal makes an initial nose poke response in the middle hole when the stimulus light is on. After initiate the trial the animal had to choose between immediate the small reward by making a nose poke response in the left hole or choose to wait for the large reward by nose poking in the right hole. The inter-trial interval between the trials was depended on the duration of the delay. The session stopped when the animals made 50 correct responses or automatically after 60 minutes. This delayed reward test was divided into 5 blocks of 10 trials. Every block the delay increases. Thus, within a session there were 5 different delays. The test was divided over 4 phases in which the delay increases in each session and between these phases. In the first phase the delay for the large reward was increased from 0 to 12 seconds within a session. In the second phase of the DRT testing, the delay increased from 0 to 24 seconds, in the third phase from 0 to 48 seconds and in the fourth phase from 0 to 60 seconds. Each animal was tested in each phase for 3 consecutive sessions until they continue to the next phase. Every block of ten trials contains two forced trials, which were not recorded. Thus, the actual data represents only eight correct trials per delay within a session. The script was not correct declared in the first phase at the first day. The session stopped after 40 correct trials instead of 50 correct trials. Therefore, the data of the first session of the first phase of 10 of the 31 rats are missing. The percentage choice for the large reward was calculated as function of the delay as the [(number of choices for the large reward)/(number choices large + small reward) × 100]. The average percentage for the large reward over the three sessions per delay was also calculated.

Statistical analysis

Training duration

The group size for the analysis of the duration of the training stadia was n=31. The five animals that did not progress to the second training phase were excluded in the analysis. The rats that did pass the training phases were categorized in the three play groups based on play behavior. The high play group contains 7 animals, the medium play group contains 16 animals and the low play group contains 8 animals. To compare the duration of each training stadium between the high-, medium- and low play group, the data were analyzed with two-way repeated measures ANOVA using SPSS statistics for Windows, version 24.0.0.1. The duration per training stadium was the depended variables. The different training stadia were the within-subjects factors and the different play groups the in-between factors of this ANOVA-model.

Preference for the large delayed reward between play groups and batches

The group size for the analysis of the preference for the large delayed reward was n= 30. One animal that did not pass all the training phases were excluded in the analysis. The rats were categorized in the two batches where they derived from: batch 1 contains 16 animals and batch 2 contains 14 animals. They were also categorized in three play groups based on play behavior. The high play group contains 6 animals, the medium play group contains 16 animals and the low play group contains 8 animals. Data were analyzed with two-way repeated measures ANOVA's using SPSS statistics for Windows, version 24.0.0.1. Each testing phase in the delayed reward test was separated analyzed. The percentages of choice for the large reward were the depended variables. The duration of the delay was the within-subjects factors and categorized in the five delays per phase. The in-between factors were the playgroups: high players, medium players and low players; the batches: 1 and 2; and the batch x playgroup interaction. The same analyses were done after excluding the medium players of the experiment.

Individual choice preferences for the large delayed reward

The group size for the analysis of the individual choice preference for the large delayed reward was n= 30. The rats were again categorized in the same batches and play groups as for the analysis of the preference for the large delayed reward between play groups and batches. First, the progressions of the choice for the large reward within each testing phase of every animal were examined (see table 2). The data were sorted in 6 groups depended on the progression of the choice for the large reward: decreased preference for the large reward (1), mostly large reward (when the choice preference were between 80 to 100 percent; 2), mostly small reward (when the choice preference were between 0-30 percent; 3), no clear progression (4), almost equal percentage(when the choice preference differs not more than 20 percent ; 5) and increased preference for the large reward (6). Data were also analyzed with two-way repeated measures ANOVA using SPSS statistics for Windows, version 24.0.0.1. The progression of percentage of the choice for the large reward was the depended variables, categorized in the 6 groups of delay depended choice for the large reward . The 4 testing phases was the within-subjects factors and the play groups, batches and the playgroup x batch interaction the in-between factors.

Results

Training duration

Overall, there was no significant effect in the duration per training stadium (Playgroup: $F(2,24) = 0.757$, NS; Batch: $F(1,24)=2.143$, NS; Playgroup x Batch: $F(2,24)=0.594$, NS; figure 2). The animals seem to have the most issues to pass the first training stadium. Five animals did not pass the first training stadium at all, and the average number of sessions required to pass the first stadium was 18 sessions. To pass this stadium they had to make minimal 30 correct responses in one session of 30 minutes, as mentioned before. All animals pass the second and third stadium in one session. The average number of sessions the rats required to complete the DRT training phase was 6. The average numbers of sessions the high-, medium - and low players needed to complete the different training stadia are shown in figure 2. Although, according to the figure, the low players seemed to learn faster in the first trainings stadia, there was no significant difference between the interaction time and playgroups or time and batches for the number of sessions required to complete the different training phases (Time x Playgroup: $F(2.8,34)=1.797$, NS; Time x Batch: $F(1.4,34)=1.162$, NS; Time x Playgroup x Batch: $F(2.8,34)=0.257$, NS; figure 2).

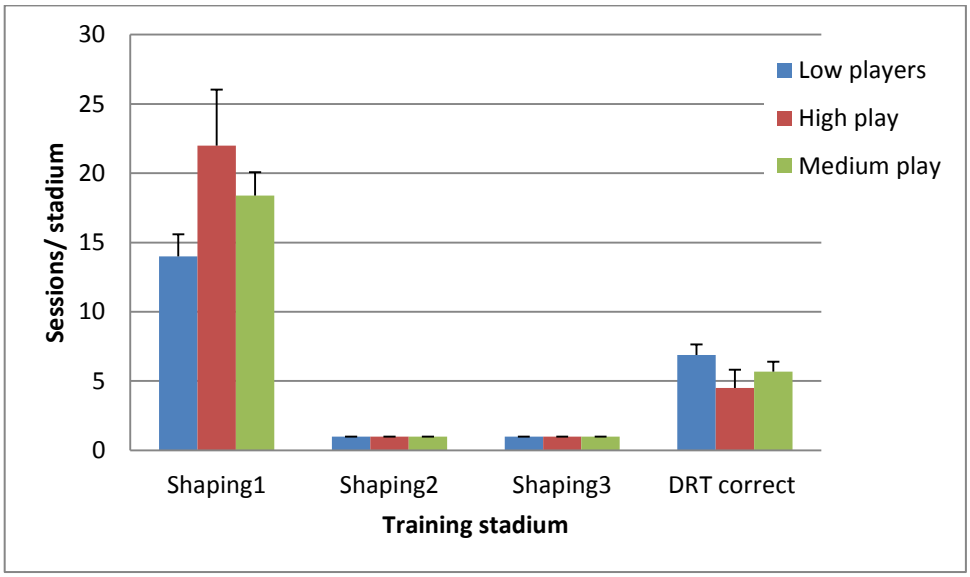


Figure 2. Number of sessions the animal required to complete the different stadia. The differences between the low-, medium-, and high players were not significant (Time x Playgroup: $F(2.8,34)=1.797$, NS). The error bars represent the standard deviation.

Preference for the large delayed reward

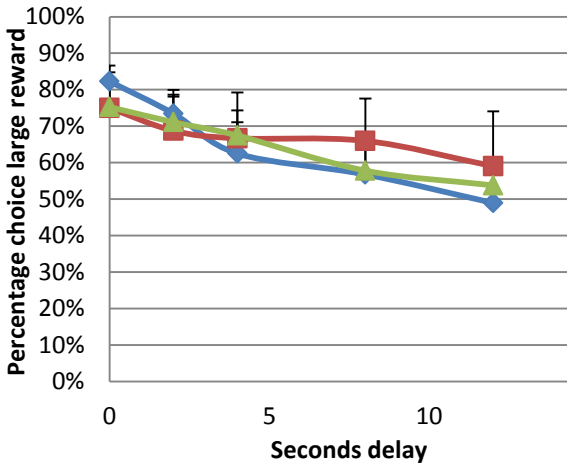
The average percentages of the choice preference for the large reward, over the three sessions, depended on the duration of the delay, is constructed in a chart as seen in figure 3a-d. In these figures the percentage choice for the large reward across the different delays is plotted for the high-, medium- and low players. Although all the figures show a descending curve in the preference for the large reward whenever the delay increases, statistical analysis of the data revealed no significant overall effect of play group on the choice for the large reward in the 12 seconds delay phase (Playgroup: $F(2,24)=0.023$, NS; figure 3a). There was also no significant effect of play group on the choice for the large reward in the 24 seconds delay phase (Playgroup: $F(2,24)=0.020$, NS; figure 3b), nor for the 48 seconds delay phase (Playgroup: $F(2,23)=0.175$, NS; figure 3c) and neither for the 60 seconds delay phase (Playgroup: $F(2,22)=0.049$, NS; figure 3d).

Statistical analysis of the batches revealed also no significant overall effect on the choice preference for the large reward when the delay increases in the 12 seconds delay phase (Batch: $F(1,24)=0.487$, NS). There was also no significant effect of batch in the 24 seconds delay phase (Batch: $F(1,24)=0.048$, NS), nor in the 48 seconds delay phase (Batch: $F(1,23)=0.170$, NS) and neither in the 60 seconds phase (Batch: $F(1,22)=0.051$, NS). There was also no overall batch depended effect on playgroup in the different phases (12 seconds delay phase: Playgroup x Batch: $F(2,24)=0.463$, NS); 24 seconds delay phase: Playgroup x Batch: $F(2,24)=0.005$, NS; 48 seconds delay phase: Playgroup x Batch: $F(2,23)=1.097$, NS; 60 seconds delay phase: Playgroup x Batch: $F(2,22)= 0.442$, NS).

Statistical analysis of the play groups and batches on the choice for the large reward, depending on the duration of the delay, revealed no difference in the 12 seconds delay phase (Time x Playgroup: $F(4.6,55)=0.986$,NS; figure 3a; Time x Batch: $F(2.3,55)=0.486$, NS). There was also no batch depended effect of playgroup on the choice for the large reward, depending on the duration of delay (Time x Playgroup x Batch: $F(4.6,55)=0.417$, NS). Moreover, there was also no significant delay depended difference between play groups and batches in the 24 seconds delay phase (Time x Playgroup: $F(4,96)=0.905$, NS; figure 3b; Time x Batch: $F(4,96)=2.196$, NS) and neither there was a batches depended effect of playgroups on the choice for the large reward depended on the duration of delay (Time x Playgroup x Batch: $F(8,96)=1.234$, NS).
Even analyzing the data of the 48 seconds delay phase there is not a delay depended difference revealed between the play groups and batches or the interaction between these factors (Time x Playgroup: $F(6.5,75)=1.313$, NS; figure 3c; Time x Batch: $F(3.2,75)=0.248$, NS; Time x Playgroup x Batch: $F(6.5,75)=1.673$, NS). Statistical analysis of the 60 seconds delay phase revealed no delay depended differences between the play groups and between the batches (Time x Playgroup: $F(7.6,83)=1.742$, NS; figure 3d; Time x Batch: $F(3.8,83)=0.630$, NS). Interestingly, after analyzing the interaction between the batches on the play groups in the choice for the large reward, depended on duration of the delay, there was a significant difference (Time x Playgroup x Batch: $F(7.6,83)=3.161$, $p<0,05$). According to these statistics there is possibly an interaction somewhere between the time, batches or play groups. However, further analyses with help of the pairwise comparisons table, revealed no significant effect between one of these factors ($p>0.05$). Thus, the sessions with the duration of delay to 60 seconds resulted also not in a significant difference between the playgroups or batches in the choice preference for the large reward, depending on the duration of the delay. The differences between the playgroups in choice for the large reward, depended on the duration of the delay, are plotted in figure 3a-d.

When the medium players were not considered, there was also no overall effect of the playgroup, batch or the interaction between playgroup and batch on the preference for the large reward in the analysis of the 12 seconds delay phase (Playgroup: $F(1,10)=0.048$, NS; Batch: $F(1,10)=0.272$, NS; Playgroup x Batch: $F(1,10)=0.966$,NS). There is also no overall effect revealed in the 24 seconds delay phase (Playgroup: $F(1,10)=0.035$, NS; Batch: $F(1,10)=0.017$, NS; Playgroup x Batch: $F(1,10)=0.000$, NS), nor in the 48 seconds delay phase (Playgroup: $F(1,10)=0.050$, NS; Batch: $F(1,10)=1.109$, NS; Playgroup x Batch: $F(1,10)=0.441$, NS) and neither in the 60 seconds delay phase (Playgroup: $F(1,8)=0.001$, NS; Batch: $F(1,8)=0.012$, NS); Playgroup x Batch: $F(1,8)=0.052$, NS). Depending on the duration of delay there were also no significant differences of preference in choosing the large over the small reward between the play groups, batches or even considering the interaction between the playgroups and the batches in the 12 seconds delay phase (Time x Playgroup: $F(2.4,24)=1.630$, NS; Time x Batch: $F(2.4,24)=0.604$, NS; Time x Playgroup x Batch: $F(2.4,24)=0,517$, NS). Also in the 24 seconds delay phase there was no significant difference in choice for the large reward, depending on delay (Time x Playgroup: $F(4,40)=0.183$, NS; Time x Batch: $F(4,40)=2.110$, NS;

Time x Playgroup x Batch: *F*(4,40)=0.326, NS), nor in the 48 seconds delay phase (Time x Playgroup: *F*(2.9,29)=1.120, NS; Time x Batch: *F*(2.9,29)=0.528, NS; Time x Playgroup x Batch: *F*(2.9,29)=1.276, NS) and neither in the 60 seconds delay phase (Time x Playgroup: *F*(4,32)=1.534, NS; Time x Batch: *F*(4,32)=1.242, NS; Time x Playgroup x Batch: F(4,32)=0.328, NS).



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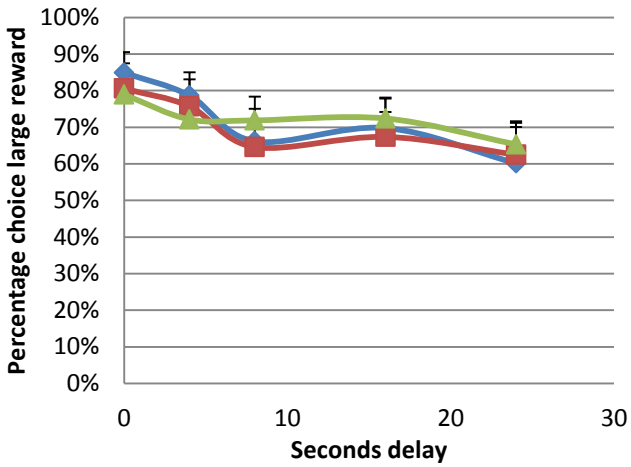

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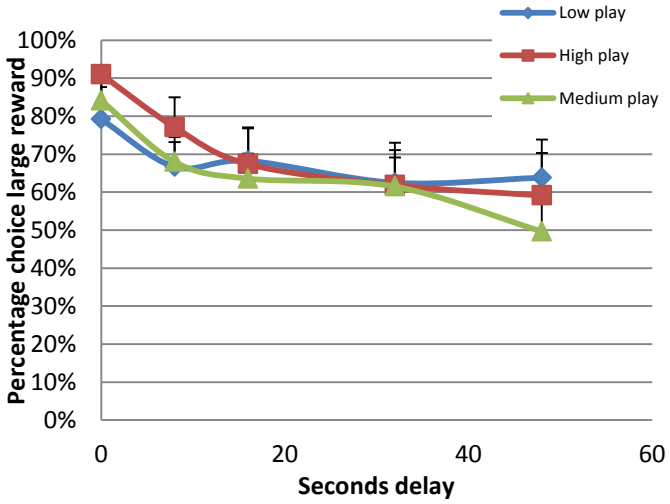

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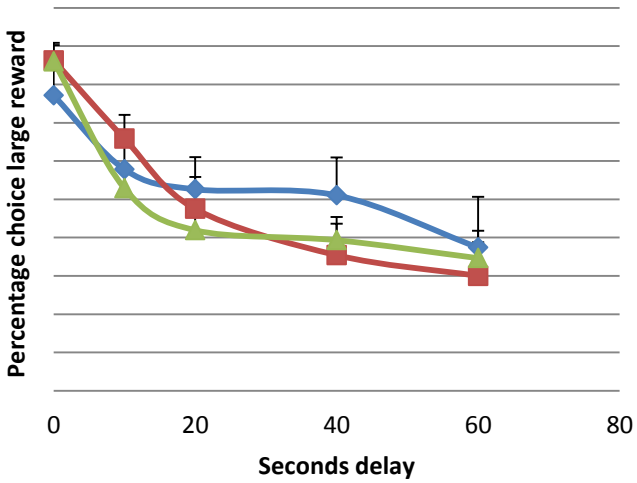

2d.

Figure 3. The average percentage of the preference for the large delayed reward over the 3 sessions is plotted as function of the duration of the delay. The duration of the delays increased within a session to 12 seconds (figure 3a), 24 seconds (figure 3b), 48 seconds (figure 3c) and 60 seconds (figure 3d). 30 animals were included in the experiment: 8 animals in de low play group, 6 animals in the high play group and 16 animals in the medium play group. The differences between the playgroups or batches were not significant in all the sessions.

Individual choice preferences for the large delayed reward

Interestingly, there are substantial individual differences in the preference for the large delayed reward. For example, rat 7 almost only chose the small immediately reward over the large delayed reward, while rat 18, 31 and 33 mostly preferred the large delayed reward. Rat 3, 18, 24 and 25 almost never had all the rewards within the 60 minutes of the session. Overall, most of the animals showed a delay dependent choice

preference for the large reward, for example rat 5, 17, 20, 25, 26, 28 and 35. However, some rats did not show a clear delay dependent choice preference, for example rat 6 and 12. The most noticeable individual differences are summarized in table 2. Analyzing the data of the individual progression of the percentage for the large reward per testing phase revealed not a significant overall effect of the playgroup, batch or batch depended effect of playgroup (Playgroup: $F(2,23)=0.717$, NS; Batch: $F(1,23)=1.655$, NS; Playgroup x Batch: $F(2,23)=1.328$). Depending on the progression of the preference for the large reward, there was also no significant difference between the playgroups, the batches or the interaction between these factors (Progression x Playgroup: $F(6,69)=0.857$, NS; Progression x Batch: $F(3,69)=0.894$, NS; Progression x Playgroup x Batch: $F(6,69)=0.466$, NS).

Rat	Batch	PlayGrp	12s	24S	48s	60s
1	1	1	Decreased (92-38%)	No clear progression	No clear progression	No clear progression
3	1	1	Decreased (79-42%)	Missing the last trials (s1,s2,s3)	Missing last trials (s1,s2,s3)	Missing last trials (s1,s2,s3)
5	1	1	Decreased (96-63%)	Missing last trials (s2,s3)	Decreased (96-29%), missing last trials (s2,s3)	Decreased (75-0%)
18	1	1	Mostly large reward (100%)	Decreased (100-83%), missing last trials (s2,s3)	Mostly large reward (between 81-100%), missing last trials (s1,s2,s3)	Decreased (100-63%), missing last trials (s1,s2,s3)
20	1	1	Decreased (67-13%)	No clear progression	Decreased (33-17%)	Decreased (71-4%)
21	2	1	Decreased (71-13%)	No clear progression	No clear progression	No clear progression
22	2	1	No clear progression	Almost equal (between 83-96%)	No clear progression	Missing last trials (s3)
27	2	1	Decreased (79-38%)	Decreased (88-33%)	No clear progression	??
2	1	2	Decreased (92-54%)	No clear progression	No clear progression	Decreased till last delay
6	1	2	Almost equal (between 83-92%)	Almost equal (between 88-100%)	No clear progression	No clear progression
7	1	2	Mostly small reward (between 0-8%)	Mostly small reward (between 0-4%)	Mostly small reward (between 0-25%)	Mostly small reward (between 0-21%)
9	1	2	Decreased (96-58%)	Decreased (100-71%)	No clear progression	No clear progression
12	1	2	Almost equal (between 71-83%)	No clear progression	Almost equal (between 92-100%)	Decreased (96-63%)
13	1	2	Decreased (88-42%)	No clear progression	Almost equal (between 83-96%)	Decreased (96-38%)
16	1	2	No clear progression	Decreased (79-46%)	No clear progression	No clear progression
17	1	2	No clear progression	No clear progression	Decreased (96-25%)	Decreased (92-25%)
24	2	2	Increased (38-58%)	Almost equal (between 45-54%), missing last trials (s1)	Missing last trials (s1,s2,s3)	Missing s2, s3
25	2	2	Decreased (96-56%), missing last trials (s2)	Missing last trials (s3)	Missing last trials (s1,s2,s3)	Decreased (88-17%), missing last trials (s1,s2)
26	2	2	Decreased (96-54%)	Decreased till last delay	No clear progression	Decreased (79-8%)
28	2	2	Decreased (92-46%)	Missing last trials (s2)	No clear progression	Decreased (92-17%)
29	2	2	Mostly large reward (between 88-100%)	No clear progression	No clear progression	No clear progression
31	2	2	Mostly large reward (between 100-92%)	Mostly large reward (between 96-88%)	No clear progression	NO clear progression
34	2	2	Decreased (83-46%)	No clear progression	No clear progression	No clear progression
35	2	2	Mostly small reward (between 13-33%)	No clear progression	Decreased (50-0%)	Decreased (67-0%)
4	1	3	Decreased (71-42%)	Missing the last trials (s1)	No clear progression	Decreased (96-17%)
10	1	3	Mostly large reward (100%)	Decreased till last delay	No clear progression	Decreased (75-46%)
19	1	3	Mostly small reward (between 0-29%)	No clear progression	Decreased (92-13%)	Decreased (94-19%), missing s3
30	2	3	Decreased (88-58%)	Missing last trials (s1)	Decreased (88-42%)	Decreased (79-13%)
32	2	3	Decreased (79-58%)	No clear progression	Decreased (100-79%), missing s2,s3	Missing all sessions
33	2	3	Mostly large reward (between 92-96%)	No clear progression	Almost equal (between 84-100%), missing last trials (s2,s3)	Missing last trials (s1), missing s3

Table 2. Individual differences in the progression of the preference for the large reward depended on the duration of the delay, over the different phases. Most of the animals showed a decreasing preference for the large reward depended on the duration of the delay, while some animals showed not a delay depended preference for the large reward or even chose the small reward over the large reward at all delays. The high playgroup is colored darker gray than the medium and low players. There were no significant differences revealed.

Discussion

This study showed not a direct relationship between play behavior of rats in weeks 4 and 5 after birth and the amount of impulsive choices later in life. Recent studies showed also no correlation between play behavior in the development of rats and the amount of impulsive actions. Overall, this suggests that play behavior in the juvenile and early adolescent phase is not direct related to impulsivity. The possibility to play during the juvenile and adolescence phase has been shown to be important in the development of cognitive control over behavior and less impulsive actions (Baarendse et al., 2013). Moreover, there are studies that showed the same abnormalities in neurotransmission in rats with play deprivation as in rats with enhanced impulsivity. This was also associated with severe changes in behavior, personality disorders and addictions. Interestingly, most of these studies examined the play deprivation due to social isolation during the lifetime of rats when play behavior is abundant (Eagle and Baunez, 2010; Pattij and Vanderschuren, 2008). Further research is necessary to relate these neural- and behavioral changes with the amount of play behavior and motivation for play.

There were several limitations to this study. First, there were 31 rats of the Lister Hooded strain included in this experiment. The possibility to use more animals from different strains may have an influence on the results. Lister hooded rats are known for their explorative behavior and therefor using another strain for this experiment might give other results due to their difference in their natural behavior. Furthermore, the diet limitations in this study may also affect the results. The rats that were used for this experiment were losing weight at the beginning of the experiment and therefor may not learn as fast as expected. The very restricted amount of chow they received could have an influence on their choice processes. At the end of the experiment there were also rats that possibly received too much food, because some rats did not had all the 50 rewards they could have in a session (Table 2). Possibly the rats may not be as hungry or they did not realize that the food was already given.
The duration of the delays and the amount of trials of every delay may also have an influence on the results. When the duration of the delays were increased to more than 60 seconds, the curves of choices for the large reward may decline more, because more animals will choose the smaller reward over the large reward when the duration of the delay increases (Ainslie, 1975). The results may also differ when testing the rats with more trials per delay. The delayed reward test is normally constructed with 12 trials per delay. In this study there were only 10 trials per delay within a session. Moreover, the script was not correct declared, which may had an influence on the data. Every block of ten trials started normally with two forced trials. In the script there were 10 trials per block but the forced trials is not gone into the data. Thus every block had eight correct trials instead of ten and the matching forced trail of some blocks came too late.

This study investigated the relation between play behavior and decisional impulsivity, but not examined this relationship the other way around. With use of the results and figures constructed in this study, there is the possibility to determine the relation between impulsive choice and play behavior the other way around. The main question would be: do the impulsive animals showed more play behavior and have more motivation to play compared to the less impulsive animals? This could be analyzed by calculating the area under the curves of preference for the large reward (figure 2) and analyses these findings as function of the play behavior. The recent study that examined the relation between play behavior and impulsive actions did this research the other way around. Apparently, the impulsive animals did play more. The impulsivity of these animals was based on impulsive actions; not impulsive choices. We suggest that rats that chose more impulsive may also played more in their development. Further research is necessary to confirm this suggestion.

Conclusion

Recently, researchers studied the relationship between play behavior and developing alcohol addiction. The high playing animals drank more alcohol, and at the same time had more control over the amount of alcohol consumption. The hypothesis that the animals had more control over the alcohol consumption was thought to be related to the augment cognitive control and thus less impulsive behavior. A recent study showed not a correlation between play behavior and impulsive action. The aim of this study was to determine whether individual differences in social play behavior are related to impulsive choice behavior. In addition, findings of the current study also did not revealed a relationship between play behavior and motivation in the juvenile and early adolescence phase of rats and impulsive choice, with use of the delayed reward test. Overall, these findings suggest that the amount of play behavior and motivation for play in the juvenile and early adolescent phase have not a direct influence on impulsivity.

References

Ainslie, G., 1975. Specious reward: a behavioral theory of impulsiveness and impulse control. *Psychological bulletin*, *82*(4), p.463.

Baarendse, P.J., Counotte, D.S., O'donnell, P. and Vanderschuren, L.J., 2013. Early social experience is critical for the development of cognitive control and dopamine modulation of prefrontal cortex function. *Neuropsychopharmacology*, *38*(8), pp.1485-1494.

Baarendse, P.J. and Vanderschuren, L.J., 2012. Dissociable effects of monoamine reuptake inhibitors on distinct forms of impulsive behavior in rats. *Psychopharmacology*, *219*(2), pp.313-326.

Cardinal, R.N., Pennicott, D.R., Lakmali, C., Robbins, T.W. and Everitt, B.J., 2001. Impulsive choice induced in rats by lesions of the nucleus accumbens core. *Science*, *292*(5526), pp.2499-2501.

Cheung, T.H. and Cardinal, R.N., 2005. Hippocampal lesions facilitate instrumental learning with delayed reinforcement but induce impulsive choice in rats. *BMC neuroscience*, *6*(1), p.36.

Dalley, J.W. and Robbins, T.W., 2017. Fractionating impulsivity: neuropsychiatric implications. *Nature Reviews Neuroscience*, *18*(3), pp.158-171.

Dickman, S.J., 1990. Functional and dysfunctional impulsivity: personality and cognitive correlates. *Journal of personality and social psychology*, *58*(1), p.95.

Fone, K.C. and Porkess, M.V., 2008. Behavioural and neurochemical effects of post-weaning social isolation in rodents—relevance to developmental neuropsychiatric disorders. *Neuroscience & Biobehavioral Reviews*, *32*(6), pp.1087-1102.

Kreek, M.J., Nielsen, D.A., Butelman, E.R. and LaForge, K.S., 2005. Genetic influences on impulsivity, risk taking, stress responsivity and vulnerability to drug abuse and addiction. *Nature neuroscience*, *8*(11), pp.1450-1457.

Lesscher, H.M., Spoelder, M., Rotte, M.D., Janssen, M.J., Hesseling, P., Lozeman-van't Klooster, J.G., Baars, A.M. and Vanderschuren, L.J., 2015. Early social isolation augments alcohol consumption in rats. *Behavioural pharmacology*, *26*(7-Special Issue Pharmacological Approaches To The Study Of Social Behaviour-Part 2: Social Modul), pp.673-680.

Spinka, M., Newberry, R.C. and Bekoff, M., 2001. Mammalian play: training for the unexpected. *The quarterly review of biology*, *76*(2), pp.141-168.

Pattij, T. and Vanderschuren, L.J., 2008. The neuropharmacology of impulsive behaviour. *Trends in pharmacological sciences*, *29*(4), pp.192-199.

Pellis, S. and Pellis, V., 2013. *The playful brain: venturing to the limits of neuroscience*. Oneworld Publications.

Winstanley, C.A., Theobald, D.E., Cardinal, R.N. and Robbins, T.W., 2004. Contrasting roles of basolateral amygdala and orbitofrontal cortex in impulsive choice. *Journal of Neuroscience*, *24*(20), pp.4718-4722.