Benchmarking Cognitive Abilities of the Brain with Computer Games

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Abstract

Most of the players have experienced the feeling of temporarily losing their character in a given gameplay situation when they cannot control the character, simply because they temporarily cannot see it. The main reasons for this feeling may be due to the interplay of the following factors: (1) the visual complexity of the game is unexpectedly increased compared with the previous time period as more and more game objects and effects are rendered on the display; (2) and/or the game is lagging; (3) and finally, it is also possible that the players have no sufficient experience with controlling the character. This paper focuses on the first reason. We have developed a benchmark program which allows its user to experience the feeling of losing character. While the user can control the character well the benchmark program will increase the visual complexity of the display. Otherwise, if the user lost the character then the program will decrease the complexity until the user will find the character again, and so on. The complexity is measured based on the number of changed pixels between two consecutive display images. Our measurements show that the average of bit per second values of losing and finding pairs describes the user well. The final goal of this research is to further develop our benchmark to a standard psychological test.

Keywords: esport, talent search, benchmark program, complexity, psychology test.

1 Introduction

Losing the control of the character in a given gameplay situation is a very common feeling that is well known among gamers. In this situation, players cannot control their character, simply because they temporarily cannot see it due to the visual complexity of the display is unexpectedly increased and/or
Figure 1: A screenshot of BrainB Test Series 6 in action. Can you find the box labelled by the name Samu Entropy in this picture?

the game is lagging and, finally, it is also possible that the players have no sufficient experience to control the character. In this paper, we introduce our benchmark computer program called BrainB Test Series 6 that can abstract this feeling. In this test, game objects are symbolized by boxes as it can be seen in Fig 1. All boxes move according to random walks. There is a distinguished box labelled by the name Samu Entropy. It represents the character controlled by the player. The benchmark test lasts for 10 minutes. During the test, the user must continuously hold and drag the mouse button on the center of Samu Entropy. If the user succeeds in this task then the benchmark program will increase the visual complexity of the display. It will draw more and more overlapping boxes which will move faster and faster. Otherwise, if the mouse pointer cannot follow the center of Samu Entropy then the visual complexity will be decreased. The test will delete more and more boxes and the remaining boxes move slower and slower until the user finds Samu Entropy again, i.e., clicks on Samu Entropy.

The BrainB Series 1 to 4 were developed in the family setting of the first author\textsuperscript{1}. Then, in our university environment, we had already done a preliminary study [BBP\textsuperscript{+}18] on a previous (BrainB Series 5) version of our benchmark. Some of its measurements were streamed live on Twitch\textsuperscript{2}. The main research goal of this study is to show that players lose the character on a higher complexity level of the display and they find it on a relatively lower complexity level.

The organization of the paper is the following. In the next section, we give a brief overview of the psychological and informatics background and the phenomenon of losing the character is illustrated. The second section presents the algorithm and the operation of our benchmark program including the presentation of the first measurements followed by systematic measurements. Finally, we conclude our paper and show some future plans.

\linebreak[3]
\textsuperscript{1}For example, see https://www.twitch.tv/videos/139186614
\linebreak[3]
\textsuperscript{2}For example, see https://www.twitch.tv/videos/206478952
1.1 Psychological Background

The cognitive ability of attention is a significant factor in everyday life, either it comes from work, hobby or the daily activities, as it affects the performance of all the previously mentioned things. The alertness, or in other words, the long upheld attention, in technical terms is called vigilance. The research of vigilance is an important topic in Psychology from 1970 to the present day. The first method used was the Mackworth Clock [Mac48], in which the participants had to pay attention to a clock that had a second hand which sometimes sprang twice, and then the participants had to signal as soon as possible. For measuring attention and concentration, there is another method, the Toulouse-Piéron test [TP13], in which participants have to follow a given scheme to separate right and wrong signs. To measure vigilance we must take into consideration the hit ratio and the number of false alarms. In almost all of our activities there are also interfering stimuli that affects our performance as well. These other factors vary by quantity and quality, and some can be stimulating, while some detain us from the optimal performance. The Yerkes-Dodson law [YD08] says that for achieving the best performance there is an optimal arousal level, which level is higher in simpler tasks, and lower in complex activities. It can be represented by a inverted U-shaped curve. We must not forget that as in some other things, in the attentional system there are also personal differences that should be taken into consideration while researching the subject [CGR07].

Other objects in the environment can affect how we perceive the one object that is interesting for us. In 1940, Witkin et al. did a research on perception [WLH+54], and from this work, they created a theory about two different cognitive styles, which they called field dependent, and field independent. A field independent person perception is mainly affected by the field, the environment of the observed object. On the contrary, a field independent person does not affected by the field created by the observed object’s environment. This phenomenon was investigated by a task, in which the participants had to determine whether a straight rod, in different planes is vertical or not. Moreover, there is another typical method used in this topic, that is the Tilting room, Tilting chair test, in which the participant is sitting in a tiltable chair that he or she needs to controll in order to get him/herself into vertical position despite the tilting room. Later, Witkin and Goodenough reinvestigated the topic, and they came to a conclusion that the two styles are two ends of the spectrum, however, some people are fixed with one of the cognitive styles, while others can adapt to the style they use depending on the situation [AWRG76].

Speaking of attention, it’s important to talk about the main processing system, i.e., the brain. The operation of the brain is frequently compared to the mechanism of a personal computer by many researchers. Carl Sagan based his theory on the binary coding, so he used the information content in binary. When we are watching something, the picture seen that our brain maps, is made of plenty of information. Sagan wanted to calculate the information processing speed of the brain, to do so, he based his calculation on the example of looking at the moon, and from this example he drew the consequence, that the brain can process about 5000 bit/sec at its peak performance [Sag12]. In a modern project, called Building 8, the main thought is to make the brain into a computer. Based on this project, the information processing speed of the brain is about a terrabyte/sec, which far exceeds the speed estimated by Sagan [Nie17].
1.1.1 Practicing filling out tests

Filling out tests and experiments are common tools in the science of psychology. Countless methods were created to date, but these methods are not just used, because researchers improve them, as well as, try to test them in a wider range. However, we need to consider certain factors in each experiment and test that how they affect the method’s usability and the final results as well. Among these factors, there is one, when the participant obtains knowledge about what is expected from her/him, or which answer are considered the ‘best’. This way the participant will accomodate to this information, because he/she, as everyone else, wants to portray herself/himself in the best manner possible and to be the ‘best’ in performance. In multiple choice questions, there are some tricks, that are well known in the common knowledge, which we all use, when we don’t know the right answer for sure. A somewhat similar tool is the experience or routine with filling out tests, which can help to choose the adequate strategy for solving the situation, this is called test-wisdom. To achieve that, one must discover the logic behind the method, or practise it many times. But the test-wisdom often cause inconvenience for test developers, because they have to keep in mind a bonus factor, which is totally diverge from the basic variables they meant to manipulate, and vary in each individual [RSA06].

The effect of being experienced in filling in tests was studied in a research, in which an aptitude test called GRE (Grand Record Examination) was used. Practise samples were sent to random participants 5 weeks before the examination. Those who got these samples also received advices for completing. In conclusion, the group with prior knowledge and practise earned significantly better results in the examination. Furthermore, there were also a notable growth in points, when the participants received an only 4 hours educational practise before the examination. It’s important to note that this difference and growth was present only in the logical reasoning part of the exam, and not in the mathematical and verbal parts [PS84]. This data was reexamined later, because researchers wanted to know, if there is any difference when the existing groups would be split into subgroups by the different attributes of the participants. As a conclusion, there was no significant difference between the subgroups, but there was a notable difference in the group in which the members’ primary language was not English, they scored lesser points than the others [Pow86].

Repeatedly performing the same experiment or test with the same participants could affect the results. Previously, as we specified, repeatedly using the same method could cause the lowering of its validity, and the results could be distorted. Participants can learn and adapt to certain methods, even if its just means a small percentage of difference. The current test takes 10 minutes to complete, in this 10 minutes the participant’s full attention and concentration is needed. We should keep in mind, that the negative effects of fatigue could balance the positive effects of practise, in a direct way of repeated examinations. So this two factors should be considered in the evaluation, and while drawing consequence.

It is therefore proposed to perform our benchmark test in a competitive way trying to beat friends, family members, colleagues or ourselves.
1.2 Informatics Background

Since computer games have a relatively short history and their effects on cognitive skills have just been started to be researched recently, there are plenty of questions to be answered. In [HPR+18], authors reported an increase in executive functions in school students after playing computer games. Moisala et al. in [MSH+17] shows that enhancements in speed and performance accuracy of working memory tasks is related to daily gaming activity. In [BAM+18], authors present an analysis of the impact of action video games on cognitive skills.

Using computer games to measure cognitive abilities has a short history, but a promising future. Most research try to measure the presence or severity of a certain cognitive disease such as dementia or Alzheimer’s disease. In [ABR+13], authors show how a long-term use of video games can reduce multitasking costs in older adults. Geyer et al. in [GIF+15] show that the change of the score of an online game is in connection with the age-related changes in working memory.

Seldom can we find applications that has been developed for the measurement of cognitive abilities. One such application is reported in [PHC15b] and [PHC15a], it is a framework that has been developed to measure cognitive abilities and its change of elders with computer games. This framework is able to log and analyze scores achieved in various online computer games.

From the viewpoint of information theory and HCI (Human-Computer Interaction), the Hick’s law [Seo05] could be an interesting aspect. This law states that the response time of the brain increases with logarithm of the size of the input. For our purposes, it can be an interesting question: how can we apply the Hick’s law (or other information theory figure) in our benchmark software?

1.3 Losing The Character

We have experienced the feeling of losing the character during playing several games like for example League of Legends3, Clash of Clans4, Clash Royale5, Heroes of the Storm6, Dota 27, World of Warcraft8 or Cabal9.

Now we share our thoughts about the phenomenon of „losing the character”, and give some examples to illustrate it from the game called League of Legends. Basically, a match starts kind of slowly and quietly: the laners are farming, as well as the junglers in their own territory. Of course smaller fights can occur in the early stages of the game, like a 1v1 in the solo lanes, or a 3v3 in the bottom lane as both of the junglers decides to gank, but these situations are relatively easy to see through. As we head into the mid and late game, teams start fights more often with more people, even with all of them. This is what we call teamfights. These are harder to handle, because a lot of things can appear on our screen at the same time: the champions who participate in the fight, optionally minions or jungle monsters, and the visual effects of the spells, summoner spells, and the active or passive abilities of the items. Besides them,

3https://na.leagueoflegends.com
4http://supercell.com/en/games/clashofclans/
5http://supercell.com/en/games/clashroyale/
6https://heroesofthestorm.com
7https://www.dota2.com
8https://worldofwarcraft.com
9http://cabal.playthisgame.com
we see a lot of things, we still have to make sure that we fulfill our ingame role properly: position well, attack the proper target, or defend our teammates. We have to handle a lot of information at a blink of an eye, so it is completely natural, that sometimes we do not know where to look at or what to do. We can lose our own character, which can end with our death; we can lose the target character, and it can survive; or we can lose the character that we wanted to protect, thus an important member of the team can die. This can be a short explanation of the phenomenon, which we can also call „losing the focus".

An example ingame footage can be viewed at [https://youtu.be/wdy3KUm1454](https://youtu.be/wdy3KUm1454), starting at 2:12.

These situations are one of the hardest parts of the game, and it is not easy to handle them well. The easiest way to prepare for them is to play a lot of games, and get experience in them. Also it can help a lot, if we think ahead before a potential teamfight, e.g. which character will be our target, who should we be afraid of, what summoner spells the enemy still has, etc. All of these things can help to execute the fights more properly.

2 Brain Benchmarking Series 6

BrainB is a Qt C++ desktop application that uses the OpenCV library. It is developed as an open source project that is available on GitHub [B17]. Its source can be built easily on GNU/Linux systems. But the latest (6.0.3) Windows binary release can also be downloaded as a ZIP file from [http://smartcity.inf.unideb.hu/~norbi/BrainBSeries6/](http://smartcity.inf.unideb.hu/~norbi/BrainBSeries6/).

It is important to show the algorithm of BrainB as precise as possible because the randomness plays a key role in its operation due to boxes doing random walks. The code snippet shown in Listing 1 is the heart of our benchmark program. It is a simplified version of the original source code that can be found in the GitHub repository at [https://github.com/nbatfai/esport-talent-search/blob/master/BrainBWin.cpp#L65](https://github.com/nbatfai/esport-talent-search/blob/master/BrainBWin.cpp#L65). This code is executed at every 100 milliseconds that is ten times per second. First, as shown in Line 1, it computes the distance between the mouse pointer and the center of the box of Samu Entropy and the result is stored in the variable called dist that holds the square of the Euclidean distance. If the distance is larger than 121 pixels (11 is the square root of 121) and if it reoccurs 12 consecutive times or more in a row (that means at least a time interval of 1.2 seconds) and it is also true that the player was controlling the character well in the previous time slices (that is in Line 10 the state is equal to found) then we say that the user has lost the character Samu Entropy and the visual complexity of the display will be saved in Line 12.

The sequence of these losing values and the symmetrical finding values saved in Line 28 are shown in Fig 2. The complexity is computed in bits per second (bps) units that is based on the number of changed pixels between two consecutive rectangular environments of the character with a given width and height.

Listing 1: The algorithm for administration of losing and finding the character.

```c++
int dist = ( this->mouse_x - x ) * ( this->mouse_x - x )
+ ( this->mouse_y - y ) * ( this->mouse_y - y );
if ( dist > 121 )
{ ++nofLost;
```
nofFound = 0;
if ( nofLost > 12 )
{
    if ( state == found && firstLost )
    {
        found2lost.push_back(brainBThread->get_bps());
    }
    firstLost = true;
    state = lost;
    nofLost = 0;
    brainBThread->decComp();
}
else
{
    ++nofFound;
    nofLost = 0;
    if ( nofFound > 12 )
    {
        if ( state == lost && firstLost )
        {
            lost2found.push_back(brainBThread->get_bps());
        }
        state = found;
        nofFound = 0;
        brainBThread->incComp();
    }
}
}

The final result printed by the benchmark after it ends in the form “U R about 5.92902 Kilobytes” is the mean of upper bounds for the bps values of the display measured when the variable state changes from found to lost (in Listing 1 from Line 10 to 14) and vice versa, when the variable state changes from lost to found (in Listing 1 from Lines 26 to 30). The simple calculation of this final result is shown in Listing 2.

Listing 2: The calculation of the final result of the benchmark that is produced in a text file that is saved in the folder where the benchmark was started.

```cpp
int m1 = mean ( lost2found );
int m2 = mean ( found2lost );
double res = ((double) m1 + (double) m2) / 2.0 / 8.0 / 1024.0;
textStream << "U,R,about", res << ",Kilobytes\n";
```

2.1 First Measurements

As concluded in our former preliminary study [BBP+18], one of the further developments of Series 5 is changing to full screen from fixed-size window. This modification affects the basic operation of the benchmark, so the first objective was to verify that whether the feeling of losing the character still appears correctly or not. On Windows systems there were no problems. Some experiments using default settings on Windows 10 can be seen in Fig 3, Fig 4 and Fig 5. But on GNU/Linux systems test subjects reported that the feeling of losing the character is not experienced. These observations will be detailed in a next section.

2.2 Logging Data

The state of the BrainB benchmark can be saved at any time by pressing the S button but measured data is automatically saved after the test is finished. The
Figure 2: The bps values associated to events of losing and finding. The first element of this sequence is the first element of the lost2found (shown in Listing 1 Line 10) sequence. The second element is the first element of the found2lost, and so on. It should be noticed that the losing (labelled by L) and finding (F) events are mixed, see, for example the 13th event on the x axis where the complexity of finding is greater than the complexity of losing in this individual measurement. This test was performed by the first author (46 years old, on a Dell XPS 9333 ultrabook with Windows 10 using the touchpad, resolution 1920x1080, scale 150%). The final result was 5.92902 Kilobytes. All the logged data can be found at http://smartcity.inf.unideb.hu/~norbi/BrainBSeries6/measurements/NB/. Fig 1 shows the last screenshot of this experiment.
(a) With using the touchpad.

(b) With using a standalone mouse.

(c) The final result was 5.45563 Kilo-bytes.

(d) The final result was 6.37927 Kilo-bytes.

Figure 3: These tests were also performed by the first author on the same environment as in Fig 2. All the logged data and final screenshots can be found at http://smartcity.inf.unideb.hu/~norbi/BrainBSeries6/measurements/NB/.
(a) 6.51813 Kilobytes (performed with the touchpad).

(b) 4.31812 Kilobytes (performed with a mouse).

(c) 6.79218 Kilobytes (performed with the touchpad).

Figure 4: This test was performed with a male child (10 years old, on the same environment as in Fig 2). The data and final screenshots can be found at http://smartcity.inf.unideb.hu/~norbi/BrainBSeries6/measurements/NaB/. It should be noted that test subjects with touchpad can use both hands, one for holding the button and the other for motion.
program saves a screenshot of the display to a PNG file. For example, such a screenshot was shown in Fig 1. The data is saved to a text file that contains the information shown in Listing 3, where the most important lines are the following. The two time values tell the time when data is saved. The first one (in Line 2) is expressed in 100 millisecond units and the second one (in Line 48) is expressed in the form minutes:seconds. The noc value tells the number of characters (boxes). The nop value tells the number of pause events initiated by the test subject. The relation symbol in Line 47 indicates the fulfillment of our research hypothesis that the mean of the complexity of changing from lost to found is less than the mean of the changing found to lost.

Listing 3: The structure of the measured data. This log file is belong to the measurement shown in Fig 3d.

```plaintext
1  NEMESPOR BrainB Test 6.0.3
2  time  : 6000
3  bps   : 28170
4  noc   : 71
5  nop   : 0
6  lost  :
7  30530 31840 39910 10960 60270 71280 50340 51880 31670
8  49260 53710 41620 86830 72880 56310 70560 68870 45500
9  52480 52660 45640 46870 44660 75860 68150 70110 69610
10 47130 61980 75310 90440 75700 62670 54870 69820 75170
11 84350 76990 80480 70840 54920 40720 33800 31590 28860
12 24680 27250 53490 58180 56200 57490 53930 39030 83870
13 87380 78270 70990 43600 52360 43910 33820 31120 34830
14 32370 32840 37080 32390
15  mean : 54181
16  var  : 18541.5
17  found :
18  12880 22240 26690 11190 19880 36170 14930 28100 25860
```
2.3 Choosing Colors

We put a lot of emphasis on what colors to choose for our benchmark. The reason for this is that even the standard test requires a constant focus of 10 minutes, which can put a lot of pressure on one’s eyes. To ease this strain as much as we possibly could, we took lots of things into account. Firstly, we tried to maximize the contrast between the background and the figures. This means that we picked some colors that could be easily distinguished and then we ran some manual tests. The result was a significant drop in the overall burden of the eyes.

After this, we thought about how we could make the benchmark available for a wider range of people, namely for those who suffer from parachromatism or even disambiguation. This is rather important as it is said that roughly 8% of men and 0.5% of women\textsuperscript{10} suffer from one of these. In order for them to be able to comfortably run our benchmark, we tried to pick colors that are easily distinguishable even for these people.

Another problem was that we did not target a specific age group. On the contrary, we were especially curious about the results of adults, adolescents, teenagers and children. Therefore, we needed to pick a color scheme that was modern, vivid, yet not too complex and not too abstract. This, too, required a lot of experimentation.

2.4 Known Problems with Series 6

Despite that our benchmark is developed on Linux it is surprising that test subjects who performed it on Linux did not experience the feeling of losing

\textsuperscript{10}http://www.color-blindness.com/2006/04/28/colorblind-population
the character. This problem causes the deteriorated results shown in Fig 6. It is important to note that it has not been detected in earlier series of the application. Moreover, before Series 6, there was no Windows binary edition of BrainB program. In Series 6, changing to full screen from windowed causes the problem because Series 6 is sensitive to the different mouse sensitivity settings on Windows and Linux systems (the measurements shown in Fig 6 were performed with a Logitech mouse with \textit{acceleration: 5/1} and \textit{threshold: 5 xset m}^1\texttt{1} setting). A short-term solution may be to standardize the test environment used by each member of a given subset of test subjects. We apply this method to perform systematic measurements with Series 6 in the next section. The long-term solution will be to fine-tune the control of movements of boxes that is hardwired into the Series 6 from Series 5 at this moment. Another possibility is to take the liberty of fine-tuning of the mouse for test subjects who thus would be able to choose their custom mouse settings in order to increase their effectiveness. This is also in well accordance with the competitive way of performing our test. Fig 7 presents two measurements using custom mouse settings.

2.5 Systematic Measurements with Series 6

The BrainB Series 6 was measured in two groups: UDPROG and DEAC-Hackers. The first one is a Facebook community of over 550 actual or former students of the BSc course of “High Level Programming Languages” at the University of Debrecen. The second one is an esport department of the University of Debrecen’s Athletic Club. Participation in the BrainB Series 6 survey was voluntary in both groups.

In the UDPROG community 33 members send back their results including the PNG screenshot and the produced text file within 2 days from the date of announcement (20 August 2018). The arithmetic mean of the final results of UDPROG participants is 4.95345. The mean of the number of boxes at the moment when the benchmark ends is 57.1818. The averaged losing and finding curve for all members is shown in Fig 8a. At the end of the curve the arithmetic mean values of complexity of the losing and finding events are irrelevant because the size of the sequences of losing and finding events are different for every participants. Fig 8b indicates these different sizes.

In the DEAC-Hackers community 12 esport athletes have sent back their results that can be seen in Fig 9. It is important to notice that despite low sample sizes of test subjects the averaged losing and finding curves shown in Fig 8a and 9a have already separated the losing and finding events.

3 Conclusion

Our research hypothesis was that the mean of the complexity of changing lost to found is less than the mean of the changing found to lost. Fig 8a and 9a show the fulfillment of this hypothesis. It seems very well in these figures that the averaged losing and finding curve has precisely separated the losing and finding events. Intuitively, this result shows that we lose the character on a higher complexity level then we find it on a relatively lower level again. This simple hypothesis has been proved by the results of this study.

\footnote{\url{https://www.x.org/archive/X11R7.7/doc/man/man1/xset.1.xhtml}}
(a) The test subject was the same as in the experiment shown in Fig 3. The final result was 3.76904 Kilobytes.

(b) The test subject was the same as in the experiment shown in Fig 4. The final result was 3.75116 Kilobytes.

(c) This final screenshot corresponds to Fig 6a.

(d) This final screenshot corresponds to Fig 6b.

Figure 6: These tests were performed on a GNU/Linux desktop (Ubuntu 16.04, SyncMaster S24B300 monitor with resolution 1920x1080). Test subjects reported that the feeling of losing the character is not experienced.
(a) The final result was 5.95587 Kilobytes. xinput settings were the following “Device Accel Constant Deceleration (277): 1.000000”, “Device Accel Velocity Scaling (279): 1.000000” and “Device Accel Profile (276): -1”

(b) The final result was 5.71674 Kilobytes. xinput settings were the following “Device Accel Constant Deceleration (277): 2.000000”, “Device Accel Velocity Scaling (279): 15.000000” and “Device Accel Profile (276): -1”

(c) This final screenshot corresponds to Fig 7a.

(d) This final screenshot corresponds to Fig 7b.

Figure 7: The test subject was the same as in the experiment shown in Fig 3. The subject reported that the feeling of losing the character has already been experienced.
(a) This figure shows the averaged losing and finding curve for all UDPROG participants where the losing (L) and finding (F) events are also indicated.

(b) The sizes of samples of losing and finding events. The x-axis shows the sizes and the y-axis shows the number of test-subjects.

Figure 8: Measurements in the community UDPROG. The arithmetic mean of the final results of UDPROG participants is 4.95345. The mean of the number of boxes at the moment when the benchmark ends is 57.1818. The anonymized data can be found at http://smartcity.inf.unideb.hu/~norbi/BrainBSeries6/measurements/UDPROG/.
(a) This figure shows the averaged losing and finding curve for all DEAC-Hackers participants where the losing (L) and finding (F) events are also indicated.

Figure 9: Measurements in the community DEAC-Hackers. The arithmetic mean of the final results of DEAC-Hackers participants is 3.71036. It is surprisingly lower than expected if compared to the value 4.95345 of the examined programming community. The mean of the number of boxes at the moment when the benchmark ends is 49. The anonymized data can be found at http://smartcity.inf.unideb.hu/~norbi/BrainBSeries6/measurements/DEACH/.
In order to further strengthen the completion of our benchmark test in a competitive way in the following versions we are going to offer to test subjects a little more liberty of fine-tuning the settings. The fine-tuning of mouse settings was already mentioned earlier. A further possibility is to allow using custom colors.

The next research objective will be to verify the satisfaction of Hick’s law. To achieve this goal it is simple enough to compare the complexity of finding and losing events with the time differences of these. Unfortunately, the actual version of the BrainB benchmark do not record these timestamps. The BrainB Series 7 will contain this feature. Our long-term research goal is to further develop our benchmark to a standard psychological test that can be used for talent search in esport.

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