New Modern Application for Gamified Memorizing Paired Facts by More Fun form of Memory Game with the Possibility of Own Content Development

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Abstract

The article deals with the technique of memorizing a larger number of pairs of related facts (e.g. words in mother tongue and foreign language) using the flashcard method transformed into the classic card Memory Game. For this purpose, the new authoring mobile application Own Memory is introduced, whose major advantage is support for creating custom card sets, complemented by many original useful options. In addition to images, the application adds support for text and sound cards that can be used both separately and combined. These features make it easier to creating of sets with an effective educational component that allows to learn paired facts with the long-time proven flashcard method, but in a much more fun form than the classic version. This learning with the game can be enjoyed separately, against the artificial intelligence of the selected level, or with friends or family even on devices with a larger screen. Thanks to the open format of cards sets, it can be prepared outside of this application in any favourite software. The development of the application Own Memory continues, but already in its current release it has proven to be a quality and useful tool for a modern way of effective learning, where it is important to store a larger number of different paired facts into the long-term memory.

Keywords

Memory Game. Application. Smart phones. Gamification. Memorizing. Drill. Flashcards. VARK.

INTRODUCTION

The *Memory Game* (also known as *Pexeso*, *Pelmanism*, *Shinkei-suijaku*, *Pairs*, *Concentration game*, …) is a classic cardboard game that helps train short-term memory. The game requires an even number of cards that are all the same on the reverse and form pairs (i.e. two cards) with the same face on the obverse. The cards are spread on the table with face at downside and two or more players trying to find these pairs. Each player can turn only two cards per turn, and all players can see their content. If they are the same, the player earns a point, otherwise the cards are turned back to face down. (Kuběna, 2010)

Players must remember the position and the image of each card to reveal it when they hit the other card in the pair. If the graphic representation of the pictures on the cards is aimed at children, for example in the form of characters from the popular children's

ISBN 978-80-7598-841-6 ISSN 2464-7470 (Print) ISSN 2464-7489 (On-line)

animated serials, they usually like to play the game (see Fig. 1), and they unconsciously practicing their memory from an early age (Wilson, et al., 2011; Hubálovská, 2015; Hubálovká, et al., 2015; Hubálovká and Hubálovský, 2016).

Figure 1: One-year child playing the memory game on the tablet.

Figure 2: Seven-year schoolgirl trains fruit and vegetable names and classification with memory game.

This game can have another educational benefit if the appropriate content on the face side of the cards is selected. In order for a player to remember of the previously turned cards as much as possible, they must somehow memorize their contents. The image itself can be a significant information that is for players desirable to retain in long-term memory for other than only game reasons. The picture can also be accompanied by a description that identifies it for the players and puts it into the right context (viz Fig. 3).

Figure 3: Sample cards with beneficial educational information

The player thus stores into the memory the word indication and graphic representation on the card, which can be transferred from the short-term memory to the long-term memory when playing the same set of cards repeatedly (Barondes and Cohen, 1968). Positive for this memorization is also to say the name on the card aloud, respectively the sound perception of the information, which also increases the enjoyment of the game.

Flashcard and The Memory Game

Another way to increase the educational impact of this game is to use different but related content on two paired cards, whose both versions and the relationship between them need to be remembered (e.g. split the picture and its description on Fig. 3). This approach is based on the so-called *flashcard* method (Wissman, et al., 2012), where on one side of the card is written a fact, a title or a task and on the other side is a solution or related

ISBN 978-80-7598-841-6 ISSN 2464-7470 (Print) ISSN 2464-7489 (On-line)

fact (e.g. English and Spanish word, mathematical example and its result, historical event name and its year, chemical symbol and an element name, etc.). In some cases, one or both of these data can also be represented graphically as an image (e.g. a geometric figure and a mathematical formula to calculate its surface or content, images and their authors, road signs and their meaning, blind maps and names of countries/cities/rivers etc.; see Fig. 2).

Learning through flashcards, sometimes also called as memorizing or drill (Palombella and Johnson, 2005), an individual performs by looking at one side of the card, trying to imagine or say out loud the content of the other side, then see if he answered correctly and remember the right answer if necessary. Right solved cards, for which we have to sure of the answer, can be put aside, and incorrectly answered cards are return back to try it again later. With the appropriate delay between attempts and the correct number of repetitions of each of them, by so-called the *spaced repetition* method (Settles and Meeder, 2016), this form of learning is very effective (Kornell, 2009). Many of computer programs exist to calculate the right and most efficient parameters (e.g. number of repetitions and delays between them), such as *SuperMemo* (Wozniak, 1990), *Anki* (Hanson and Brown, 2019), *Memostation* (Cakula, et al., 2013) etc. (Voborník and Němec, 2019; Němec, et al., 2016a; Němec, 2017)

Transforming *flashcards* into the *Memory Game*, i.e. dividing a two-sided card into two pair cards, which are needed to be found and identified, can be beneficial in several cases. First, it allows, or rather requires, joint learning in more than one person. It can also keep players' attention longer if they enjoy playing more than just memorizing facts. Knowing the relationship between two cards in a pair is motivated especially because of that the player could succeed in the game at all.

METHODS

The methods implemented in *Own Memory* multimedia application to streamline the educational components (Milková, 2012) of the game include *flashcard* method (Kornell, 2009), a modified version of Ebbinghaus's curve of forgetting (Ebbinghaus, 1885) for simulating artificial intelligence for automatic opponents and the method using multiple perception channels to effectively memorize related data (Kim and Gilman, 2008; Němec, 2019), so partly also the VARK method (Othman and Amiruddin, 2010).

The development of the *Own Memory* application has been implemented by means of the multi-platform technology of Xamarin.Forms (Hermes, 2015). It allows a common code in language C#, respectively the XAML design definition, to compile into a native application for operating systems of Android, iOS and Windows 10 (UWP – Universal Windows Platform). (Voborník, 2019)

RESULTS

Own Memory[1] application in the first stage was created as this classic game (Borkovec, et al., 2013) for finding two identical images that gamers could import themselves from their

[1] Official website of the *Own Memory* application is www.own-memory.com. The app is available on Google Play and the Microsoft Store.

ISBN 978-80-7598-841-6 ISSN 2464-7470 (Print) ISSN 2464-7489 (On-line)

own photo gallery on a mobile device or computer (see Fig. 4). Gradually the app was extended to include all the above-mentioned educational possibilities, plus some others. Emphasis was also placed on the overall openness and versatility of the solution, providing the possibility of using third parties.

Figure 4: Own Memory game in classic mode.

The set of cards for the game is therefore basically only a few image files, each used twice. These sets can be created directly in the application environment (see Fig. 12). All imported images are automatically cut to a square aspect ratio, shrink to 512x512 pixels and saving as a JPG image with 80% quality. However, in order to create or edit sets without these limits outside of *Own Memory* app, a classic ZIP archive was used as the format for storing these sets, that only has changed file extension from ZIP to OMS (*Own Memory Set*) for file type resolution. All you have to do is select images on your computer or mobile phone in any browser, wrap them in a ZIP archive, change the extension to OMS, and the memory card set is ready for import into the application.

Picture cards

However, if is needed to take advantage of the advanced capabilities of the application, especially in the field of education, then just rename the image files in the set. For creating of a pair which has different pictures on both cards, a wavy line character (~) is using. The beginning of the name (prefix) of the cards files in the pair must be identical, different is in the part after the separating character of the wavy line (postfix). For example, files in a pair can be named *card2~a.jpg* and *card2~b.jpg*, or *car~en.png* and *car~es.png*. The files with pictures in the set can be named arbitrarily, but if this notation is followed (even if only on some of files in the set), the principle of different pictures in one pair will be used.

If there are more than two image files with the same name prefix, two of them are randomly selected and used when shuffling cards. The other variants can then be selected in the next game. It works similarly with the total number of cards. If there are more cards than is needed for the game, only the selected number of cards/files/pictures in a pair is randomly selected from the whole set at the start of each game.

ISBN 978-80-7598-841-6 ISSN 2464-7470 (Print) ISSN 2464-7489 (On-line)

If the set contains any localization items, such as tab text in different languages, just add another parameter to the file name. From more language versions is selected just one by the national settings of the operating system where the application is running. Dot before file extension can be used for separation of the culture code (two chars ISO 639-1; Morey, et al., 2013) at the end of file name. E.g. if there are *card3.en.jpg*, *card3.es.jpg* and *card3.jpg* files, the first image will be shown only for English localization, second only for Spanish and the third for every other language.

Text cards

If the picture on the card should be only text, it would be unnecessarily laborious to create such a picture manually, the picture would be unnecessarily data-intensive, and the text would be blurred due to rasterization. The same applies to any descriptions below the pictures. For this reason, XML card support has been added. An XML card is a text file with an extension and format of XML (Bray, et al., 2008). Its structure is shown by the following code. Not all of elements and attributes are required.

```
<?xml version="1.0" encoding="utf-8"?>
<card background="#FFAAFFAA" textColor="#FF000000">
    <text>carrot</text>
    <label>vegetable</label>
    <info>The carrot is a root vegetable…</info>
</card>
```

Fig. 5 shows how this XML card definition is edited in the application. The text on the card (element *text*), if defined, is shown in the centre over its entire card's surface. The card label (element *bottom*) is the text on the bottom of the card. Additional information (element *info*) is displayed in the dialog by clicking on the rotated card, and this text can be longer and multiline. If the image is to be combined with the text and it is too dark, the text color on the card (attribute *textColor*) can also be changed to make it readable, and/or the background color of the card (attribute *background*) around the image, respectively below its completely or partly transparent pixels, or instead of whole image. Both colors can be defined including the alpha channel value, i.e. the degree of transparency.

ISBN 978-80-7598-841-6 ISSN 2464-7470 (Print) ISSN 2464-7489 (On-line)

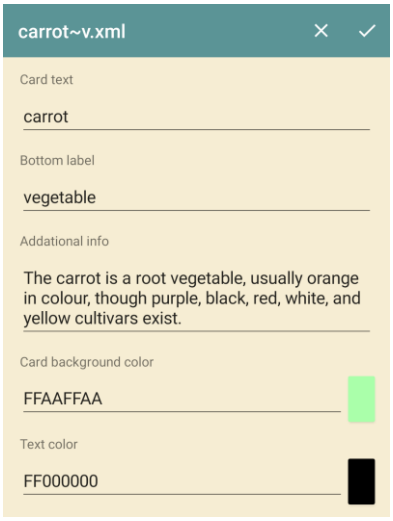

Figure 5: Form for editing XML card details.

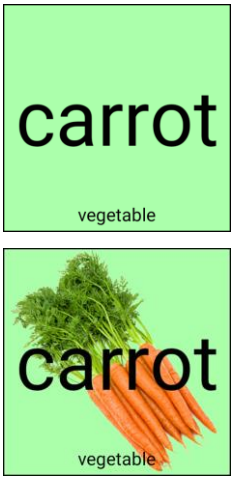

Figure 6: Example of rendered card without picture and in combination with picture.

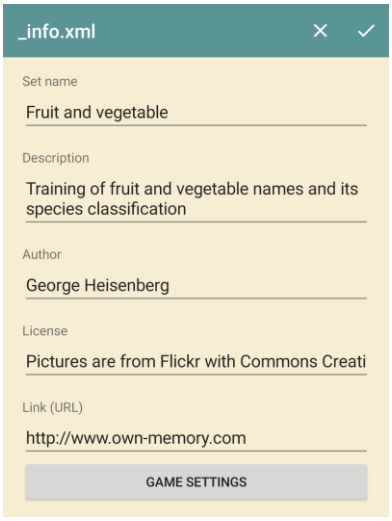

Figure 7: Form for editing set information.

As shown in Fig. 6, the text and the picture on the card can be combined. For this variant is necessary to name both files (with image and XML) the same so that only their extensions differ (e.g. *card4.jpg* and *card4.xml*). This allows to define only the label of the card and this text appears as additional information below the image without the need to edit the image itself.

Sound cards

The images and texts provide the visual side of the cards. However, some people better remember sound perceptions and everybody a combination of both (Kim and Gilman, 2008; Němec, et al., 2016b; Němec, et al., 2016c). Especially when learning foreign languages, listening to the pronunciation of vocabulary words is very important (Yeh and Wang, 2003). For this reason, support for audio files has been added to *Own Memory* app.

The same rules apply for file names as for picture and XML cards. If the audio file name is unique, then the contents of the card will be empty, but its sound will be played when the card is rotated from back to front side. The sound can also be played again by clicking on the already rotated card. If an image (or even text) is present with the same file name in the set, everything for that card will be combined together.

File naming system in the set

Supported extensions of the files for specific card types are:

- **Images:** JPG, JPEG, PNG
- **Audio files:** MP3, WAV
- **Text data:** XML

Any other file types in the set are ignored. In future versions is also planned a support of vector images SVG and GIF animations.

ISBN 978-80-7598-841-6 ISSN 2464-7470 (Print) ISSN 2464-7489 (On-line)

There may also be several special files in the set with specific reserved names that begin with an underscore (_). These add more information about the set as a whole or set the implicit default content (colors, texts, images or sounds) for all cards that are used only when some cards do not explicitly (individually) define them.

- **_info**.* (data) – information about set (name, description, author, license, URL and color settings of the play board; see Fig. 7)
- **_back**.* (image/data) – image and/or text data for back of cards of the whole set (if absents, default background image from the app will be used)
- **_theme**.* (image) – image that is used in the sets list (see Fig. 11)
- **_default**.* (image/data/audio) – image, audio and/or text data used for cards without image, audio or text data (at least one of these file types must exists for card identification, other may be defaults); if this name has a suffix (e.g. "~a" or "~b", i.e. there are files *_default~a.jpg* and *_default~b.jpg*) then these default images (or data or audio) will be linked with all cards with the same suffix
- **_turn-card**.* (audio) – a default sound for turn a card
- **_pair**.* (audio) – a default sound when the whole pair is turned
- **_pair~yes**.* (audio) – a sound when the pair of the same cards is founded
- **_pair~no**.* (audio) – a sound when the pair of a different cards is turned
- **_end**.* (audio) – a default sound for the end of the game
- **_end~human**.* (audio) – a default sound for the end of the game when human wins over computer
- **_end~computer**.* (audio) – a default sound for the end of the game when computer wins over man
- **_end~both**.* (audio) – a default sound for the end of the game when computer and man has the same score or when plays computers only

Thus, the definition of default files (*_default* for images, sounds, and texts) can be individually replaced by specific cards if their file variant is present. Default values can be also specified specially for different cards in a one specific pair (files with wavy lines in the name). Simply name them with a common base from the file name (part before the tilde). For example, if the cards in the pair are to have the same image and sound when rotated but different labels, these files should be inserted into the set: *card5~a.xml*, *card5~b.xml*, *card5.jpg* and *card5.mp3*.

This optional system of gradual settings properties can minimize the need to repeat the same files in the set (see Fig. 8).

Figure 8: Example of hierarchical validity of properties and cards content settings from the most general (left) to the most specific (right) for the *card~x*.

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Game options

The conditions under which the game will run can be also set in the *Own Memory* app (see Fig. 9). The timing of the pauses between moves can be specified, and thus the time to remember the cards turned in the current turn. Default sound effects of cards rotating (not explicitly defined audio files in a set) can also be deactivated to avoid distracting. It is also possible to set whether the same player should continue or not with playing after finding a pair of cards, which both variants are valid in different versions of the Memory Game rules.

Defined can also be the transparency of found pairs of cards, so that they do not disturb the rest of the game but remain available in case they display additional information or play audio when clicked. However, when the visibility is set to 0%, found cards disappears completely from the board. Some other settings can also change the whole game mode.

When this option *Show all cards at the beginning* is enabled, all playing cards will face up for the selected time interval as soon as a new game begins. Players can then try to remember the content and location of as many of them as possible and after their turn to back to quickly find these pairs again. This variant is another interesting alternative for memory training, especially suitable for a single player game.

Option *Auto start a new game when a previous ends* displays a table with a summary of each player's score after the end of the game, but the *Play again* button launch a 10-second countdown and after it a new game automatically starts with the same settings. While this option may seem unimportant for classic gaming, it allows the application to be used for presentation purposes. This option, along with the setting to play a computer for all players, would allow the game to run in an endless fully automatic loop. For example, if some firm created a set of images of their products (goods, school campus photos, travel agency photos of destinations …), thanks to this function, it can be projected on an unattended screen or projector to attract potential customers at an exhibition, at doors open days or at shop window as an interesting form of presentation.

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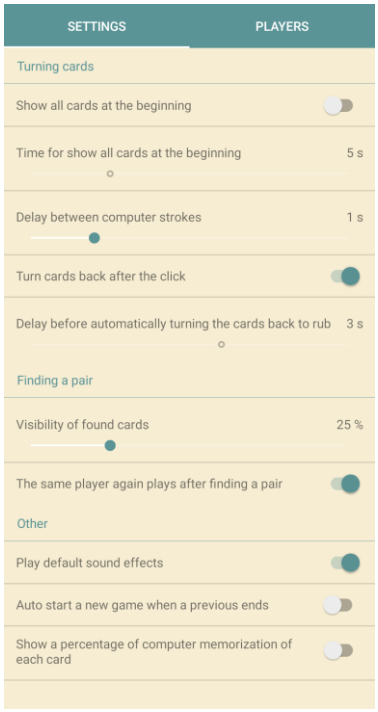

Figure 9: Game settings.

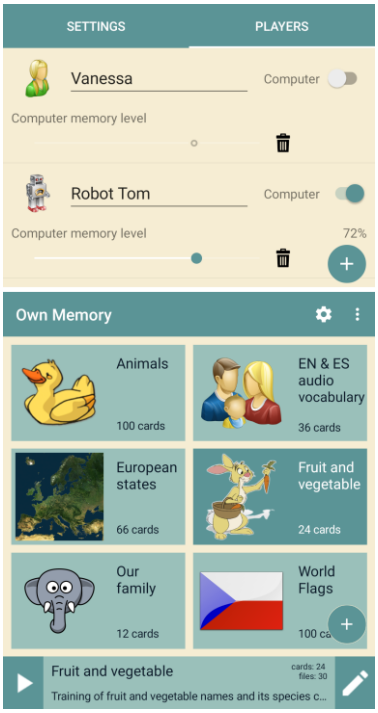

Figure 10 (top): Players settings. Figure 11 (bottom): Sets list.

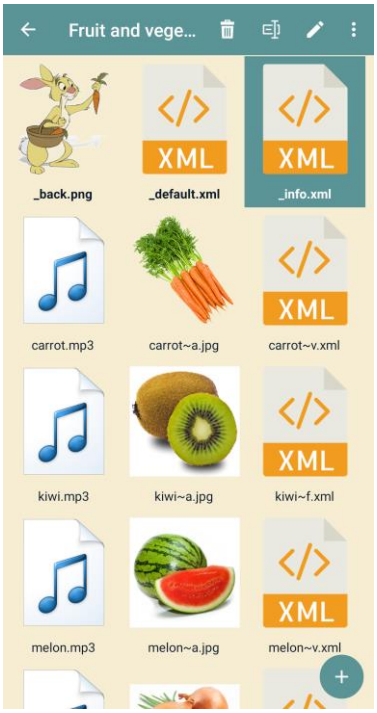

Figure 12: Cards (files) in the set.

Presentation sets should also be assisted by the upcoming feature to start playing a new set in the application directly via a special URL[2]. The application would start and immediately start playing with this external set of cards only by clicking on such this URL link in the browser (Milková and Ambrožová, 2018). The teacher could thus prepare a set of cards suitable for the current subject matter and provide it to the pupils simply by publishing its link, for example, through an e-learning environment (Hubálovský, 2013; Hubálovský, et al., 2019).

When the computer player plays then activated option *Show a percentage of computer memorization of each card* will display a percentage at the right-bottom corner on the back of all non-turned cards on the board, that indicating the degree of assurance of the content of this card for the automatic player. The game can be played not only by one player itself or with any number of human opponents (on one device), but also with any number of players controlled by the computer. Players settings is on the second tab (see Fig. 10) and their number may be increased or decreased at will except the last one. The option *computer* can be activated to each of them and set their memory level too.

Artificial intelligence of an inhuman player

A model of artificial intelligence for players marked as *computer* was included into the application in order to increase variability, enjoyment of playing by one person and at the same time motivation to play more often and, in case of suitable educational sets, a learning (Hubálovský and Šedivý, 2013).

[2] E.g. "own-memory://www.some-copany.com/marketing/main-products.oms"

ISBN 978-80-7598-841-6 ISSN 2464-7470 (Print) ISSN 2464-7489 (On-line)

This model was inspired by the *Ebbinghaus forgetting curve* (Ebbinghaus, 1885) adapted for the *Re-wise* method (LANGMaster, 2012), which has already been used, for example, in the *Universal Testing Environment* (Voborník, 2012) for intelligently mixing test questions (Voborník, 2016). However, in this case, this is not a simulation of long-term memory, but only a short-term memory. Thus, cannot be counted in days, but only in game rounds.

In this modified model, the *computer* player would halve his knowledge of the content of previously rotated card in each round. If he encountered on the second card in a pair he would have a 50% chance to reveal the right card in the next round, after two rounds only 25%, then 12.5% etc. (see Fig. 13).

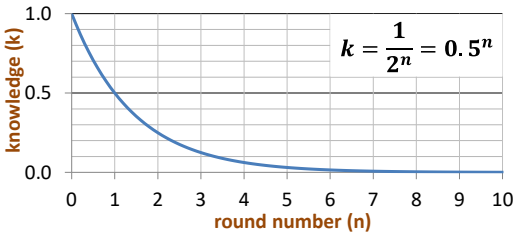

Figure 13: Forgetting curve according to the *Re-wise* method.

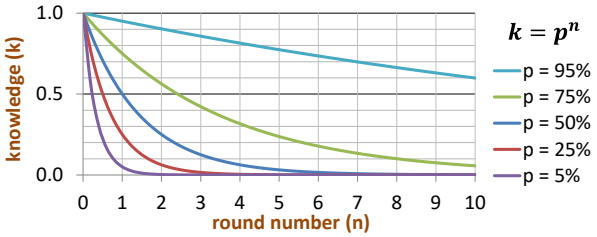

Figure 14: Modification of the forgetting curve for simulation of AI in the memory game.

However, such a decrease is too fast for short-term memory. At the same time, it was necessary to give the users the ability to adjust the level of automatic opponents to best match of their current individual abilities. For this reason, the parameter *p* has been added to the original equation instead of ½ (50%), which can be set in a percentage scale of 0–100%, i.e. in the range ⟨0, 1⟩, to define the degree of memory quality, respectively the ability of the automatic player to keep the card in memory (see Fig. 14). The knowledge of the content of the card *k* can then be determined by the equation for the given round *n* at the level of the automatic player *p* (1).

$$k = p^n \tag{1}$$

When adjusting the level of an automatic player, it can be intuitively assumed that 50% will be average level, but this does not correspond to half the loss of knowledge in each round. By experiments and simulation tables have found that to the average player corresponds the value $p \approx 75\%$, meaning that the knowledge level of the previously viewed card is reduced by only a quarter (25%) in each round, i.e. to 75% of the previous round (100%, 75%, 56.25%...). It was also necessary to mitigate too slowly changing thresholds ($x \to 0^+ \vee x \to 1^-$). For example, 10% (i.e. 90% loss of knowledge in each round) is also a more unusable value than would be expected and more corresponding is value $p \approx 25\%$ for this level. On the other hand, at 90% the level of knowledge decreases too quickly and a smaller decrease of around 3% (i.e. $p \approx 97\%$) would be more appropriate. The user-defined percentage level (x) should therefore be adjusted ($p = f(x)$) before being used in the selected model of forgetting.

A function that would convert user-selected percentages to percentages with expected properties should be concave, symmetrically curved to upward, passing at the beginning of

ISBN 978-80-7598-841-6 ISSN 2464-7470 (Print) ISSN 2464-7489 (On-line)

[0, 0] and 100% at [1, 1], which would also be the limit for its use. Logically, the $y = \sqrt{x}$ function is offered in the range of ⟨0, 1⟩. But this function is not symmetrical at both ends of the usage limits (see Fig. 15). The left upper quarter of the unit circle shifted by its radius to the right provides symmetry, correct shape and range. Basic equation of the circle taking into account this shift is $(x - r)^2 + y^2 = r^2$, and expressed for *y* it is $y = \sqrt{r^2 - (x - r)^2}$. However, the circle with radius *r* = 1 is too concave (see Fig. 15) and the input value *x* would be transformed by *y* = *f* (*x*) to beyond the expected values.

The concavity of a circle decreases as its radius increases (*r* > 1) in the 1x1 viewport (see Fig. 17). Thus, by determining the appropriate radius could meet all the requirements for this function. For this purpose, it was necessary to correctly shift the viewport 1x1, resp. calculate the coordinates of its lower left corner [x_s, y_s] (viz Fig. 16).

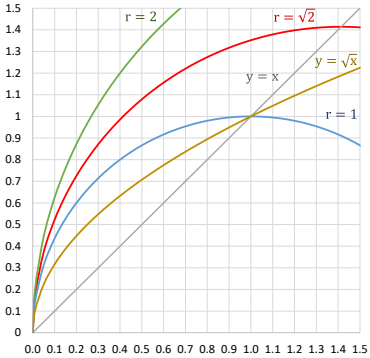

Figure 15: Candidates for transformation function of selected level to parameter *p*.

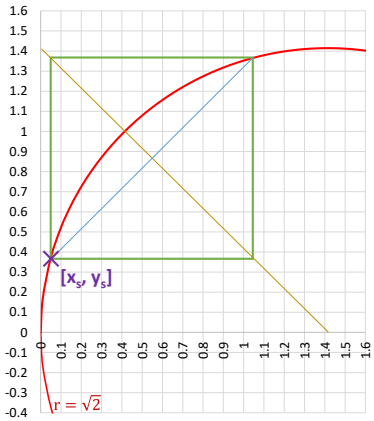

Figure 16: Representation of the 1x1 cutout the required part of the circle.

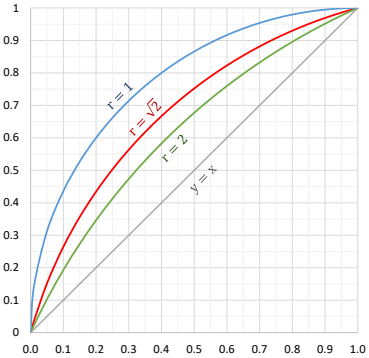

Figure 17: Comparison of the concavity of cutouts of circles of different radii.

After appropriate adjustments of the equation of the circle and the line between points [0, *r*] and [*r*, 0], when was searched *x* for such *y* where the horizontal distance of the point on the circle from this line was exactly 1, the following equations (2) of shift coordinates for the unit viewport x_s and y_s was derived.

$$x_s = \frac{2r - 1 - \sqrt{2r^2 - 1}}{2}$$
$$y_s = r - (x_s + 1) \qquad (2)$$

After calculating the shift coordinates for the selected radius and substituting into the original equation of a circle, we get the resulting function (3) that in the range of ⟨0, 1⟩ converts the selected level of the automatic player (*x*) to the value expected (*y*, resp. *p*) for the calculation in the equation (1).

$$y = \sqrt{r^2 - (x + x_s - r)^2} - y_s \qquad (3)$$

ISBN 978-80-7598-841-6 ISSN 2464-7470 (Print) ISSN 2464-7489 (On-line)

As the ideal radius of the circle for the transformation function, the value of $r = \sqrt{2}$ was empirically determined, which was closest to all selected coordinates of the expected values.

In the case of repeated turning of the same card in different rounds, the knowledge is summed by the same way as the predicted knowledge of the questions in UTE (see (Voborník, 2016) including the derivation of the function), as shown by the function rule (4), where k_x indicates the remaining knowledge of the card in any of its x turns.

$$f(x) = k_x + (1 - k_x) \cdot f(x - 1)$$
$$f(0) = 0 \tag{4}$$

Whether the automatic player turns the right card or not is decided by chance, respectively a randomly generated number in the range of ⟨0, 1), which if less than the overall knowledge of the card's contents, the player reverses it, if not, randomly selects from all non-turned cards for which he does not remember their contents by this way. Similarly, he also tries to remember the position of both cards in a pair before the first one of them is turned.

CONCLUSION

Own Memory application at first glance brings another variation on the classic board Memory Game in a new modern design. From this point of view, it is certainly interesting to create your own card sets from gallery on a mobile device, where nothing prevents players from using their favourite pictures or family photos and enjoy the game separately, against the artificial intelligence of the chosen level, or with friends or family even to larger screen devices (support for Xbox One console is planned). Thanks to the open format of OMS sets, which is essentially a classic ZIP archive, sets can be prepared outside of this application in any favourite software. Finished sets can then be used not only by the author, but can also be sent to pupils or classmates, or even shared publicly as a full-fledged teaching tool.

However, *Own Memory* app does not stay with just pictures when it comes to creating custom sets but extends the capabilities with text and audio information that can be used both separately and combined. These features make it easier to creating of sets with an effective educational component that allows to learn paired facts with the long-time proven *flashcard* method, but in a much more fun form than the classic version.

ACKNOWLEDGEMENT

This research has been supported by Department of Applied Cybernetics on Faculty of Science on University of Hradec Králové.

ISBN 978-80-7598-841-6 ISSN 2464-7470 (Print) ISSN 2464-7489 (On-line)

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