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THE INFLUENCE OF COLOURS ON EMOTIONAL MEMORY: HOW COLOURS CAN IMPROVE LEARNING IN PRIMARY SCHOOL CHILDREN

L'INFLUENZA DEI COLORI SULLA MEMORIA EMOTIVA: COME I COLORI POSSONO IMPLEMENTARE IL PROCESSO DI APPRENDIMENTO IN BAMBINI DELLA SCUOLA PRIMARIA

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Abstract

This research investigates whether colours could improve memory performance and therefore the learning process in primary school children.

Research has amply demonstrated how an emotional stimulus is codified and recalled more quickly; furthermore positive emotions make memorization easier than neutral and negative ones; other studies have reported how certain colours elicit certain emotions and therefore coloured stimuli can improve their memorization.

It is a quantitative experimental research where were administered questionnaires and tests to a sample of 72 primary school subjects; then were compared the coloured words remembered to the neutral ones.

Therefore, using colours that lead to positive emotions can help children to memorize the stimuli as the amygdala intervenes in the mnestic process.

This would improve the learning process of children and in particular could become a valuable resource for those children who present a DSA.

Abstract

La presente ricerca indaga se i colori possono implementare il processo di memorizzazione e il processo di apprendimento in bambini della scuola primaria.

La letteratura scientifica ha ampliamente dimostrato come uno stimolo con valenza emotiva sia codificato e rievocato più rapidamente. Partendo da questi studi, è emerso come in particolare le emozioni positive rendono più semplice la memorizzazione rispetto a quelle neutre e a quelle negative. Altri studi hanno riportato come determinati colori siano in grado di suscitare specifiche emozioni e che quindi determinati stimoli colorati possono migliorare la memorizzazione degli stessi.

È stato realizzato un disegno di ricerca sperimentale quantitativa in cui sono stati sottoposti questionari e test ad un campione di 72 soggetti della scuola primaria; è stata poi condotta un'analisi incrociata dei risultati ottenuti, confrontando le parole colorate ricordate rispetto a quelle neutre.

Dunque la possibilità di avere informazioni visive colorate con colori che elicitano emozioni positive può fornire ai bambini un aiuto nella memorizzazione degli stimoli stessi in quanto l'amigdala interviene nel processo mnestico.

Questo consentirebbe di migliorare il processo di apprendimento dei bambini ed in particolare potrebbe diventare una valida risorsa per quei bambini che presentano un DSA.

Key-words
Emotional memory, emotions and colours, memory and colours, primary school, NEPSY
Memoria Emotiva, emozioni e colori, memoria e colori, scuola primaria, NEPSY

Introduction

Emotional memory is the ability to recall a memory both in its mental representation and in its emotional component; emotion therefore plays a fundamental role in facilitating the process of storing and retrieving information.

The main characteristic is the presence of a synergy between the mnestic processes and the emotions, which define the value and give priority to the information: this happens thanks to the emotional excitement present in all the emotional stimuli, which therefore create a privileged channel for the passage of information (Madan et al., 2021).

Much research in recent years has focused on investigating the impact that this cognitive function has on learning and teaching in general, since emotion plays a very important role also in learning, helping young people to recall relevant information and memories.

Recent studies have shown that colour plays a significant role in influencing and improving memory performance (Madan et al., 2019). It was found that colour generates a specific effect on memory, the "colour superiority effect", which allows for a preferential way of processing; colour is assumed to enrich and make more specific memory traces, allow faster detection of objects and influence the allocation of attention (Sattarzade et al., 2021; Doğan, 2020).

Colour is a powerful visual stimulus, capable of conveying precise information. The literature has shown that it has a strong impact on children, classifying it as a non-lexical stimulus that communicates information rapidly, bypassing language, age and species barriers (Kramer et al., 2019; Tyng et al., 2017; Al-Ayash et al., 2016; Gil et al., 2016).

Based on this assumption, some researchers investigated whether there was a connection between specific colours and certain emotions, and reported positive results: particular colours arouse specific emotions. Therefore, it has been hypothesised that colours can improve or enhance the functioning of emotional memory and that applying these concepts to teaching would improve or facilitate the learning process of children.

This research, one of the first to investigate the impact of colours on emotional memory in children (as far as the author knows), has shown that there is indeed a greater memorization for coloured words than for achromatic ones. It was also observed that there is an effective relationship between green and positive emotions and that this has led to a greater memorization of the words reported in this colour.

1. The relationship between emotions and colours

Colour is a monochromatic or polychromatic light, consisting of only one or more electromagnetic radiation of certain wavelengths (Treccani).

Colours have three specific properties: shade, or the dominant length of the electromagnetic spectrum; brightness, which corresponds to the total amount of light reflected by a surface; saturation is the intensity of the colour. The colour consists mainly of green, red and blue light (Falcinelli, 2017).

Colour vision is the ability of every organism to differentiate objects according to the wavelength of the light they reflect, emit or transmit. What you see is not the colour of the object, but only the colours reflected by its surface are perceived.

In the vision of colour, a beam of light rays, reflecting from every point of the object, reaches the eye, entering the pupil, which regulates the amount of light. Subsequently, the lens, which is responsible for focusing, concentrates the rays in one area on the retina, forming the retinal image of the object. The retina is composed of two types of photoreceptors, cones and rods.

The cones, about six million, are found mainly in the centre of the retina and are sensitive to shapes and colours. There are three types, each sensitive to different wavelengths: about 420 nm, or the spectrum of blue, 530 nm, of green, 560 nm, of red.

Sticks, on the other hand, are found mainly at the edge of the retina and transmit black and white information to the brain. There are about 120 million, they are most active at night because they are unable to distinguish colours (Witzel et al., 2018). The cones therefore detect the wavelength, but they are not the authors of the final elaboration of the stimulus. Colour perception is given by a complex process that arises from the output of information from the photoreceptors and ends in the associative cortex of the brain.

Thus, the cones and rods undergo biochemical transformations from which the nerve impulse originates, which will be sent to the visual cortex and the associative cortex, where a higher level of processing will be carried out that will allow colour discrimination (Shepard et al., 2017; Hansen et al., 2013).

Investigating the impact of colour on human behaviour, it emerged how responses to colour vision can be both physiological and emotional-psychological. Some studies (Fugate et al., 2020; Thorstenson et al., 2018) have shown changes in blood pressure, respiratory rate and even body temperature. For example, exposure to red leads to a faster heartbeat, a higher blood pressure and a stronger sense of smell. In contrast, blue causes a slowing of heart rate, lower body temperature and decreased appetite (Hittle et al., 2022; Zerbini et al., 2020).

Psychological responses to colour, on the other hand, include changes in mood, attention and perception of emotion (Liu et al., 2018; Takahashi et al., 2017). The brain can release a hormone that affects moods, mental clarity and energy level.

In addition, several studies have highlighted how colour is an optical stimulus capable of communicating information quickly, subtly and across language, age and even species barriers (Ram, 2021; Mitsuhiko, 2017).

Based on these findings, many researchers have focused on understanding the strong impact of colours on people’s emotions and lives.

The way in which human beings associate colour with emotion can be explained by two not mutually exclusive hypotheses: phylogenetic hypothesis says that these associations can be mainly linked to the evolutionary process, while the ontogenetic hypothesis says that they can be explained by a series of learnings in the reference context.

The first hypothesis is therefore based on the assumption that these associations are intrinsically rooted in the subjects at the biological level, which is why it is natural and universal to attribute specific colours, emotions and meanings.

Indeed, Changizi (2006) and Changizi (2009) stated that trichromatic vision has evolved to allow primates and humans to detect subtle changes in blood flow under the skin, which provide important information on the emotional state of the conspecific. Increased redness can transmit anger, embarrassment or sexual arousal, while increased bluish or greenish tint can transmit diseases or bad physiological conditions. Thus, visual sensitivity to these colour modulations facilitates various forms of social interaction.

To support the second hypothesis, the ontogenetic one, Elliot et al. (2012) proposed the "Colour-in-context Theory", which is mainly based on social learning. According to this perspective, responses to chromatic stimuli can be determined by the exclusive combination of colour with particular concepts, messages and experiences, or by a biological predisposition that is strengthened and shaped by social learning.

To sum up, the emotional interpretation of a colour can derive from a biological predisposition and can also be influenced by a series of learning events in the context of reference.

One element that seems to influence the type of emotional response elicited is the wavelength of colour. A widely accepted view is that long-wave colours, such as red, can cause greater excitement than short-wave colours, such as blue (Güneş et al., 2020; Ikeda, 2019; Kramer et al., 2019). A study by Jacobs et al. (1974) tested the variation in skin conductance in the responses of some subjects placed in different light environments; the results showed a higher level of excitation in the red context, followed by green, yellow and blue.

The literature has therefore highlighted how colours actually have a decisive impact on subjects and how they lead to the elicitation of specific emotions, but it is necessary to understand how relevant also the intensity and shade of the colour, not only his presence.

The colour that has been most investigated is red, whose default response seems to be negative, while the literature on other colours is still relatively uncertain.

Khan et al. (2011) conducted an interesting experiment on male rhesus macaques, in order to investigate the biological character of the emotional response to red; the study reports that the negative response to red is linked to a deep biological predisposition that tends to associate it with a warning signal; this effect has been found in different cultures.

Lower performance has been observed when individuals are exposed to this colour, rather than to another colour (Gil et al., 2016), due to its hazard warning function and it involves a process of avoidance, resulting in reduced performance (Thorstenson, 2015; Shi et al., 2015; Houtman et al., 2013; Gnambs et al., 2010).

Regarding green, however, some studies have highlighted how it is associated with positive emotions, such as joy (Chai et al. 2019; Kuhbandner et al., 2013). The association between green and positive emotion, according to Yong et al. (2012), can derive from the flora, as well

as from the impact in everyday use (i.e. traffic lights); it could also be related to the wavelength of the colour, which causes a greater activation than that of blue, but less intense than that of red. Perhaps this middle way allows for the ideal activation state, which allows you to achieve optimal performance.
Regarding blue, it is associated with being comfortable, relaxing, peaceful, and calming, which can reduce stress and anxiety levels (Chai et al., 2019; Kuhbandner et al., 2013).

1.2 The relationship between emotions and colours in children

Colours are an important part of children's lives, which is why, in recent decades, many researchers have focused on understanding their role and meaning.
Because of the impact of colours on emotions, many researchers have focused on understanding whether certain colours elicit specific emotions in children.
In adults there was already evidence of a correlation between colours and emotions; however, initially in children it was difficult to carry out research on this subject, due to the difficulty of investigation and the still evolving brain structures.
In most developmental studies, the emotion-colour bond has been studied through drawings. The basic idea was that children's use of particular colours reflected the emotional charge of their drawings, thus providing a means of accessing an emotional state that was difficult to verbalise. The researches of Burkitt et al. have provided the first experimental evidence on the association between emotions and colour choice. Initially, the children completed a questionnaire to investigate their colour preferences; then they were asked to colour pictures they had designed (Burkitt et al., 2003) or designed themselves (Burkitt et al., 2004), depicting different subjects identified as positive, negative or neutral. Children used their favourite colours for positive drawings, the least favourite colours for negative drawings, and colours with a medium preference for neutral ones.
One of the first studies that investigated the association with red colour in children was that of Karp et al. (1988), where subjects, aged 9-10, were asked to associate at first impact a single colour for each of the 12 concepts presented; the association between rabies and red emerged.
Later studies have used the emotionality of facial expressions. Palmer et al. (2013) proposed a research in which children were asked to indicate a colour consistent with a facial expression, and found an association between angry faces and reddish colours.
In a face categorization task, Young et al. (2013) showed that red priming facilitates the categorization of angry faces against happy ones, compared to green or achromatic priming.
Finally, Gil et al. (2015) presented faces with ambiguous expressions on four types of coloured backgrounds, namely red, green and two control, mixed and achromatic. Participants had to say as quickly as possible whether each face expressed a broadly positive or broadly negative emotion. The results showed that faces presented on a red background were classified as negative, much more often than when presented on a different background. This highlights a strong negative significance for red.
Overall, it can be concluded that for children red is associated with aggression and anger.
Another important study was conducted by Kramer et al. (2019), which involved 120 children aged 3-10; ten concepts depicted by images were used for the administration. Six versions were presented for each, differing only in the colour of the garments. For each series, it was investigated which version best resembled the concept that concerned it.

In the image "child copying the task", for example, the one dressed in red was more associated with the concept, while the one dressed in green was more "honest."
It emerged that the colour of the garments greatly influenced the perception of the concept.
As with adults, much of the literature has focused on investigating the impact of red, with little exploration of the relationship with other colours.
In children, green evokes positive emotions, such as happiness and joy (Kramer et al., 2019; Mammarella et al., 2016).
Blue is linked to moods such as calmness and reflection (AL-Ayash, 2016; Burkitt et al., 2013) and has a calming effect on heart rate, breathing and lowers body temperature (Chai et al., 2019; Kuhbandner et al., 2013). This type of influence seems to be mainly related, as previously mentioned, to the wavelength of the colour.
It has also been found that, although there seems to be a predisposition in the interpretation of some colours, this is not entirely universal. With the exception of red, where the literature is unanimous in affirming that it is linked to danger and thus to avoidance processes, for the other colours there are many inter-individual differences which are closely linked to personal experience.

2. The relationship between colours and emotional memory

Emotional memory is a type of implicit memory, very fast, which is activated by sensory experience and allows information to be stored for so long as to define it as permanent.
The main characteristic is the presence of a synergy between the mnestic processes and the emotions, which define the value and give priority to the information: this happens thanks to the emotional excitement present in all the emotional stimuli, which therefore create a privileged channel for the passage of information (Cipollone, 2021; Madan et al., 2021).
Literature has confirmed how the amygdala plays a primary role both in the acquisition and expression of emotional memory and is therefore the creator of responses to emotional stimuli. Specifically, memory enhancement takes place thanks to the connection between amygdala and hippocampus, which are activated synergistically during the coding of information, and thanks to a complex network of connections between several areas of the brain such as base ganglia, lateral prefrontal cortex, anterior cingulate and ventral orbitofrontal cortex e media (Cunningham et al., 2021; Kark et al., 2020; Madan et al., 2017).
Researchers stated that emotional valence has a significant impact on memory and that negative valence can limit the memory process (Moore, 2021; Kensinger et al., 2018).
Recent studies have shown that colour plays a significant role in influencing and improving memory performance (Madan et al., 2019). It was found that colour generates a specific effect on memory, the "colour superiority effect", which allows for a preferential way of processing; colour is assumed to enrich and make more specific memory traces, allow faster detection of objects and influence the allocation of attention (Doğan, 2020; Sattarzade et al., 2021). It has emerged that there is a correlation between the mnestic process and colour and that the influence of colour is concretized regardless of whether it is the most prominent stimulus.
In support of this hypothesis, recent studies have discovered how the information given by colour is the basis for faster detection of objects in a scene and thus influences the allocation of attention (Katlein et al. 2021; Martinovic et al., 2018). Perez (2018) conducted a study that

showed that people remember more words written with coloured ink than those written in black and white.

This field of investigation has recently captured the attention of researchers on emotions, as it has been shown that emotions have a strong relationship with colours.

In fact, a recent line of studies (Gil et al., 2015; Kuhbandner et al., 2013) suggests that colour can also have an affective connotation and/or direct emotional reactions towards a positive or negative pole. Furthermore, the literature has now confirmed that emotion modulates implicit and explicit memory in the context of emotional memory (Kark et al., 2020).

As a result, colours can also have implications for memory tasks and can influence the processing of emotions.

Studies by Hess et al. (2013) have reported how perceptual characteristics, such as colour, can also be considered as a signal that gives specific emotional meaning to stimuli and consequently leads to differences in valence elaboration; therefore, this would imply that specific colours could elicit specific emotions.

A very important research in this field was carried out by Kuhbandner et al. (2013), in which they investigated the influence of colours on emotional memory. Starting from the literature evidence on the strong influence of emotions on memory and the positive relationship between emotions and colours, the authors wanted to investigate whether green implied an enhancement, and conversely if red implied a limitation, in the storage of information. The research showed that there was an influence on memory induced by emotions and that the mnestic enhancement for coloured words was further enhanced by their emotional significance: green words had a positive outcome, while red words had a negative outcome. So the discovery of specific effects given by the valence of different colours indicates that the emotional and perceptual salience can interact to produce an improvement of memory.

Considering these data, red and green may affect emotional memory differently, even when colour is not particularly relevant.

A research by Mammarella et al. (2016) investigated the positive effects of green stimuli on the process of storing information. The selected colours were red, green and blue. As with the previous experiment, red words were expected to inhibit memory, green words to improve memory, while blue words were expected to have no particular effect. Both groups showed better memory performance in the presence of green stimuli, compared to the red or blue ones.

In conclusion, although this field of research is relatively barely explored, the literature reports that green elicits a positive emotion, leading to an improvement in the memory process; red, on the other hand, seems to limit the storage of information, as it arouses a negative emotion. Blue was primarily used as a control colour, explicitly due to its low-exciting properties (Chai et al., 2019; Madan et al., 2018; Mammarella et al., 2016; Kuhbandner et al., 2013). There are as yet no studies concerning in-depth investigations into other shades of colour.

3. Research

3.1 Research hypothesis

As shown by the above scientific evidence, there is a close connection between emotional memory and colours, since the latter have the ability to capture the subject's attention and elicit specific emotions.

It is only recently that scientific research has come to grips with this field, and it is therefore barely explored. There is evidence of a correlation between emotional memory and colour in adults and adolescents, but research on children has not yet been conducted.

The present study aims at verifying the impact of colours on emotional memory in school-aged children. This specific age group was selected in relation to the high learning potential of the subjects.

3.2 Sample

The sample consisted of 72 subjects, aged 7-11 years, from different Italian regions. Exclusion criteria concerned the presence of colour blindness or problems in colour perception, WM disorders and low level of understanding and recognition of emotions. For this reason, the sample taken into consideration was composed of 68 subjects.

3.3 Tools

In order to carry out the present study, an experimental protocol composed of several assessment instruments was created: to investigate the level of understanding and recognition of emotions, were used tests belonging to the NEPSY-II battery. To investigate the preferences and personal values of colours, an individual questionnaire. To investigate the memorization of the words, a spontaneous re-enactment test (Kuhbandner et al. (2013) was used. The research carried out by these authors was aimed at an adult sample, but was adapted to the sample of this study, on the advice of the authors themselves, in order not to alter the validity and replicability of the research.

3.3.1 NEPSY-II

The NEPSY-II is a battery of psychometric tests, which provides a neuropsychological evaluation of the cognitive abilities of subjects from 3 to 16 years of age, in relation to specific cognitive domains. The tool allows both a global assessment and a survey aimed at one or more domains and is able to ascertain cognitive abilities or typical disorders generally diagnosable for the first time during childhood (Cipollone et al., 2021).

The tests used are those related to social perception. They are aimed at evaluating two fundamental skills of perception and social cognition: the recognition of emotions through facial expressions and the ability to decode and interpret the intentions of others and their points of view and understand how these influence their behaviour. Specifically, there are two domains:

(1) S01 TOM (Theory of Mind) is in turn made up of two parts that evaluate different aspects of the ability to understand mental constructs (beliefs, intentions, deceptions, emotions, fantasy, fiction) and the ability to understand that others they have their thoughts, ideas, feelings that can diverge from ours. Various scenarios are read to the child, or figures are shown, then they are asked questions that require understanding the other's point of view. The second part is non-verbal and assesses the ability to understand how emotions connect to a

social context and recognize the appropriate mood that the various social contexts presuppose. They show the child a figure that represents a certain social context and is asked to choose a photo – out of four possibilities – that depicts the correct mood of one of the people in the images (Morsanuto et al., 2020).
(2) Test S02 Recognition of emotions, which assesses the ability to recognize emotional expressions through photos of children's faces. The test consists of four tests that increase in difficulty (Morsanuto et al., 2019).

3.3.2 Questionnaire about colour

This tool was included in this research with the aim of investigating children's individual preferences about colours.
The questionnaire consists of two parts. The first investigates the child's favourite and least favourite colours: it is essential to consider this individual variable when investigating the impact of colour on emotional memory. In a second part, children were presented with nine monochrome images (red, green, blue, yellow, brown, pink, purple, grey, black) and were asked to declare the emotion they experienced at the sight of colour, in order to investigate the subjective emotional value, which may differ from that reported in literature.

3.3.3 Spontaneous recall tests

The spontaneous recall test was taken from the above-mentioned study by Kuhbandner et al., carried out on a sample of 48 university students, and was recalibrated as follows on the youngest sample, thanks to the authors' advice.
The protocol administered presents 9 lists of 10 words, all composed of five or six letters. The nouns in B/W are neutral, generated with the software used in the search of Kuhbandner and Pekrun (WordGen) and then translated into Italian, respecting the set word length. The coloured words are 9 in total, that is three red, three green and three blue, of which one is neutral, one positive and one negative for each colour category. In each list, one of these words was placed in fifth or sixth place in order to be affected by recency or primacy effects. At the conclusion of the spontaneous recall test, subjects were asked to rate the valence of the words, on a Likert scale from 1 (I hate this word) to 5 (I love this word) in order to determine personal valence and meaning of each coloured word presented.

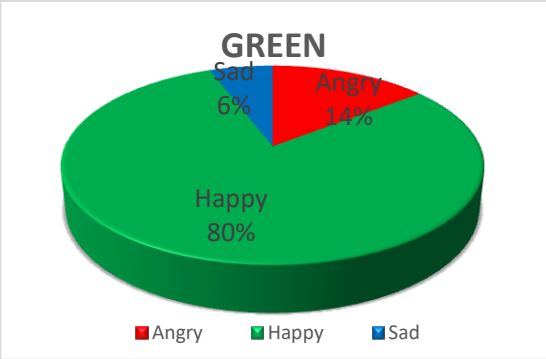
3.4 Method

Given the particular emergency situation relating to the pandemic, it was decided to develop a tool that could be comfortable and could easily reach families in quarantine. An online tool has therefore been developed that can be disseminated through the web. All the test have therefore been reported entirely on the Google Modules platform. To limit the criticalities of online administration, a webcam-monitoring administration was performed. In order not to influence or intimidate the children, it was decided to have the test administered to the parent. An initial telephone contact made it possible to provide a brief introduction to the test and to make an appointment to carry it out. Parents were asked to open the video call in the absence of the child, in order to provide some basic instructions to not influence the test. After any questions from the parents, the administrator closed their audio and video and the parent minimised the call screen: in this way the child did not know that there was an external administrator and therefore perceived a lower level of anxiety and stress. Subsequently, the

parent proceeded to the autonomous administration of the test, reading the questions to the child and allowing him to answer spontaneously. A small break was allowed if the child had experienced particular tiredness. Finally, the parent sent the test, dismissed the child and provided some feedback to the examiner. Throughout the test, the examiner would compile an observation grid about the child's response patterns and possible parental influence and/or interference, or external variables.

A consent form and information sheet were provided to all participants. Informed consent was negotiated with the children involved and re-negotiated during the time the research was carried out. Pseudonyms have replaced the names of participants. Participants (including child participants) were given the opportunity to withdraw from the study at any time.

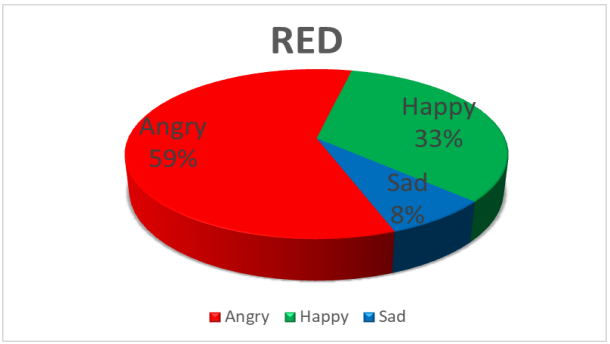
3.5 Results



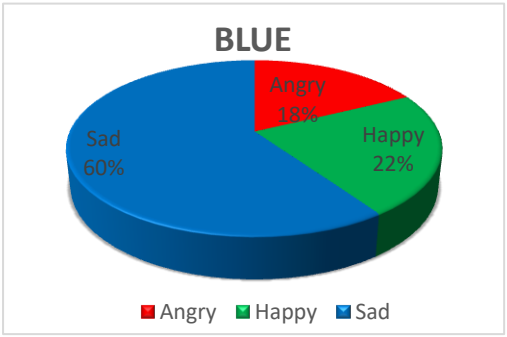
Graph. 1 Emotional valence of colour green

The graph 1 shows the emotional valence that the sample attributed to the colour green. In line with the findings of previous research, green was linked to positive and exciting emotions at 80%.

The graph 2 shows the emotional valence of the colour red for which the sample did not give an unequivocal emotional response, but in 59% of cases it was associated with anger.

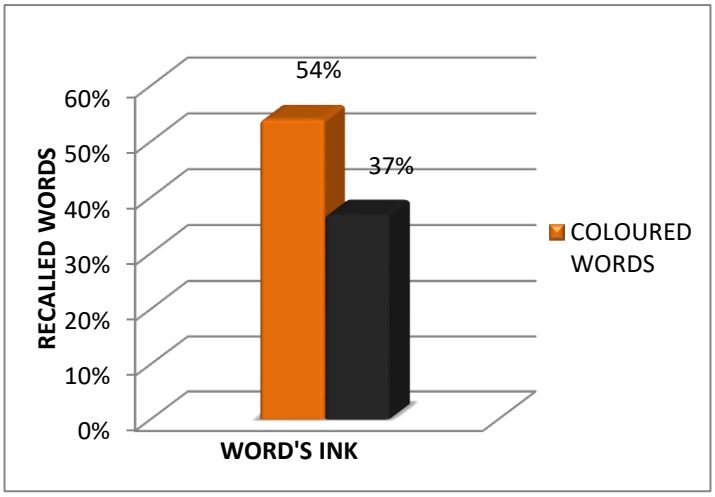


Graph. 2 Emotional valence of colour red



Graph. 3 Emotional valence of colour blue

In the graph 3 a differentiated perception of blue emerges, even if it was more associated with sadness.

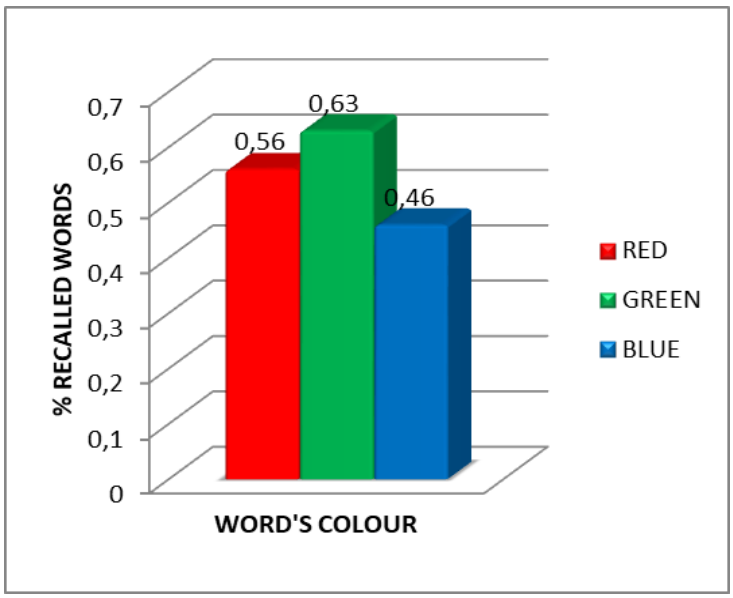


Graph. 4 Words remembered by the sample

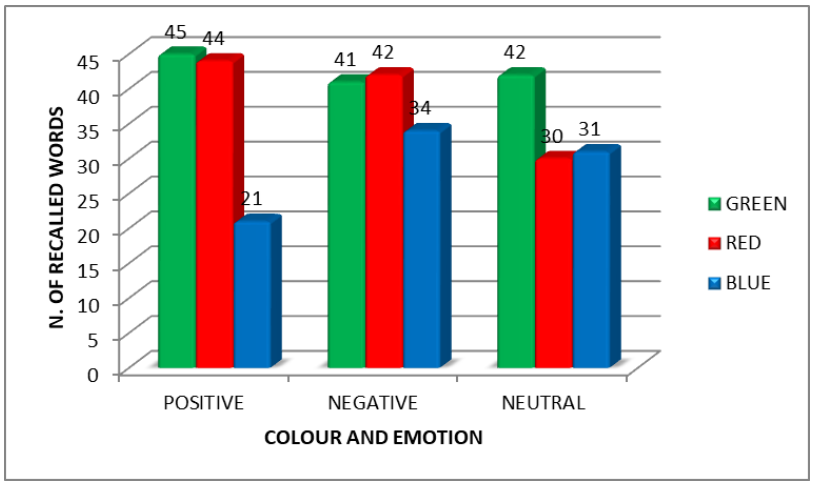
The graph 4 shows the percentage of words remembered by the sample, highlighting how coloured words were remembered 17% more than achromatic words, even considering their position within the list.

The graph 5 shows the percentages of coloured words remembered, among which green words stand out, with 63%, followed by red words, with 56% and finally blue words, recalled in 46% of cases.

This subdivision partly reflects what is present in the literature, about the strong value of the colour green in enhancing mnestic processes, but it is contrary to previous research regarding the influence of red and blue. Moreover, the results do not show a large discrepancy between the colours in the percentages of recall.



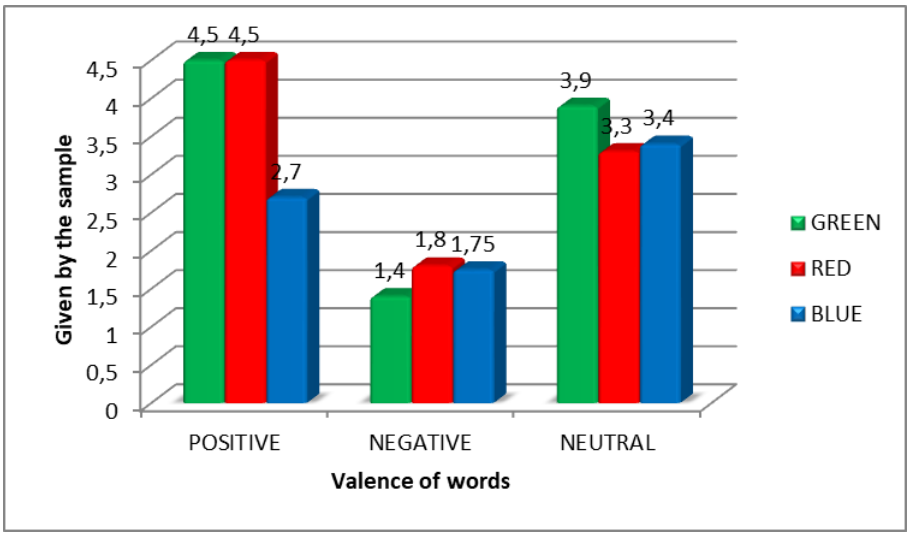
Graph. 5 Coloured words remembered by the sample



Graph. 6 Coloured words remembered in relation to emotional

This graph shows the coloured words remembered in relation to emotional valence. Within the test a word was inserted for each of the basic emotional conditions (positive, negative, neutral) in order to detect whether the valence of the word itself could influence the

mnestic process, and specifically whether this was due to a concordance between the emotional valence of the word and the emotional valence of the colour. This graph shows that the most remembered category of words was positive green, indicating how the emotional valence of the word and the colour green could have influenced memorization. The least remembered category instead was blue positive: literature has shown that a positive emotion should determine an improvement in memory, but in this case, the colour blue could have interfered with memorization, having such an impact that it could be considered more relevant than the emotional valence of the word itself. The emotional valence of colours could therefore have a greater influence than the emotional valence of words.



Graph. 7 Coloured words remembered by the sample

This graph reports the emotional valence attributed to coloured words. The sample was then asked to rate the emotional valence of coloured words in order to understand whether they were actually perceived as such. A 5-point Likert scale was used, where point 1 and 2 corresponds to a negative valence, point corresponds to an emotional neutrality, and finally points 4 and 5 refers to a positive valence. It is evident that all the words were perceived as predetermined, with the exception of the positive blue word, "fate", maybe determined by the lack of knowledge of its meaning.

3.6 Discussion

Observation of the results obtained showed that coloured words are actually remembered more, compared to words in black ink, despite their position within the list.

It is important to note that in the Google Module it was not possible to view the videos in full screen: as a result, there were also many other colourful stimuli (such as advertisements and pop-ups) on the screen that could have distracted the subject's attention from the test. It would therefore be interesting and necessary to propose the same protocol again here.

In agreement with what emerged from the literature, the colour green was also evaluated by children as positive and exciting; moreover, in line with what was expected, words written with this colour were the most remembered. In contrast to previous research, however, red was not attributed a homogeneously negative valence: this could represent the reason why the percentage of recollection of red words was very high, differing little from green words. The sample judged the colour red as strong, exciting as well as linked to anger: literature has

shown how a colour which has a strong index of excitement or which is linked to a positive emotion, can positively influence memorization. Therefore the explanation of this positive effect on memorization can be attributed to the exciting value that the sample of this research has attributed to the colour red. Moreover, the results show that the least remembered word is positive blue: this data is very interesting because it suggests that the valence of the word itself is less relevant than the valence given by the colour of the word.

It could be inferred that there is no strict correlation between the two valences and that the valence linked to the colour has a privileged path in the elaboration or that it has a greater impact on memorization, due to the influence given by the colour and by the emotions elicited by the colour itself.

From these results, it emerged a positive correlation between emotional memory and colours, confirming that colours are indeed carriers of emotional valence and that this synergy strongly influences mnestic processes. Specifically, it has emerged a good relationship between green and positive emotions, and therefore between this colour and mnemonic enhancement.

Due to the limitations of the online mode, it is essential to reproduce this research in presence, in order to determine more stable correlations between the variables considered.

Conclusions

Emotional memory, which structures the formation and recovery of memories on the emotions experienced in daily experiences, plays a fundamental role in people's lives and therefore also has a strong impact on learning processes: "I feel, therefore, I learn" (Immordino-Yang, 2017).

The literature has shown that there is a close correlation between colours and the emotions they elicit: this area has been extensively explored and its practical use in learning environments has been evaluated. Recent research has shown that there is indeed a close relationship between green and positive emotions, red and negative emotions, while blue is associated with states of serenity and tranquillity.

In recent years, starting from the above assumptions, an important strand of research has been focusing on determining the relationship between colour and emotional memory, and therefore what impact this may have on the learning processes of subjects. The studies mainly focused on an adult sample.

This research, one of the first to investigate the impact of colours on emotional memory in children (as far as the author knows), has shown that there is indeed a greater memorization for coloured words than for achromatic ones. It was also observed that there is an effective relationship between green and positive emotions and that this has led to a greater memorization of the words reported in this colour.

This study highlights the importance of knowing the emotional value and therefore the choice of colours for each child in the teaching environment: being a strong stimulus, possessing this information would allow us to intuit and manipulate the effect it could have, such as customising some spaces in the classrooms.

Adequate colour scheme in classrooms and study materials could facilitate the learning process and help children with more difficulties, such as ASDs. For example, some research reports that the use of a coloured overlays, a plastic reading sheets tinted with colour and placed over text, can eliminate or alleviate a wide range of reading difficulties such as low

reading rate, accuracy, and comprehension in dyslexia (Jakovljević et al., 2021; Denton et al., 2016, Hlengwa et al., 2017).

Thus, the above evidence underlines that colour has the ability to influence students' attention, behaviour and results. Therefore, it would be advisable to consider functional aspects rather than aesthetics, because the excess stimulation through colour creates a sensory overload, similarly, colourless interior spaces can be stressful and unproductive. In other words, an under-stimulating environment can be as harmful as an over-stimulating one. Choosing an appropriate colour in classrooms and learning processes is becoming increasingly important because of the contribution it can make to students, especially students with disabilities, because of their greater sensitivity to it.

This research, however, aims to be only a rudimentary beginning of a much larger project, which will allow us to deepen the correlation that has emerged, in order to analyse its applications in the school environment.

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