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SERIOUS COMICS FOR SCIENCE POPULARIZATION: IMPACT OF SUBJECTIVE AFFINITIES AND THE CRUCIAL ROLE OF COMIC FIGURES

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Abstract

Comics are pervasive in everyday life and often are about scientific topics, thus entertainingly transmitting scientific knowledge. This pioneering study on such serious comics examines the role of emotional and cognitive affinities of the recipients towards the comic figures and its influences on the reception process considering motivational and cognitive factors. Participants read a comic in which a scientist demonstrates the quantum physics thought experiment on "Schrödinger's cat" with the dog of one of the protagonists. After that, they answered questions on emotional (liking of animals) and cognitive (need for cognition) affinities. Further, we assessed motivational indicators (e.g., liking of the comic) and participants' understanding of the comic and its scientific content. Our results indicate that emotional and cognitive affinities defined the preference for a comic figure. Afterwards, the favourite comic figure influenced the scientific understanding, depending on how close the comic figure was connected with the scientific content. We discuss these results in the context of the use of comics for scientific knowledge acquisition.

Keywords: Serious comics, science communication, science popularization, comic figures, subjective affinities, quantum physics, instructional design.

1 INTRODUCTION

1.1 Serious Comics for Science Communication

One of the most critical challenges of science communication to the broad public is how to engage people who are indifferent to science and how to create interest in and understanding scientific findings for those people. One answer to this question could be edutainment. Edutainment is a long-term trend in learning and information communication that aims to provide information entertainingly and appealingly. Thus, it is of particular importance for voluntary learning [1].

Serious comics [2] are a unique form of edutainment and can be understood in analogy to serious games. Serious comics are a combination of pictures and written text that uses the art form and unique language of comics [3] [4] for an appealing and entertaining communication of academic information. Roughly said, serious comics can be seen as a unique mixture of linear multimedia instructions and entertaining comics. As an illustrating example Linek and Eckhorst [5] created a serious comic that explains what serious comics are. The idea of using the motivational potential of comics (or graphic novels) for educational or more “serious” aims is not new. Farinella [6] gives a good overview of the existing research on comics with scientific content. Thus far, most of these initiatives are pragmatic and general. Systematic research on specific design variables or person-related variables is relatively sparse and it is still an open question whether and if so, how subjective learner preferences and unique design characteristics of comics influence motivation and learning success.

In contrast to the mentioned literature on science comics, the label “serious comics” relates to a research-based approach with the general aim of more systematic investigations on the potential of science comics and comics with educational or informative content. The study presented in this paper is a first step in gaining deeper insights into the value of serious comics and an optimized, personalized design for different learner groups. Accordingly, the general appeal of a comic has different subcomponents. Besides the artistic appeal of the drawings and the included texts, the cognitive and emotional appeal of a comic are essential because they are possible drivers of motivational processes in the form of interest and involvement. The cognitive appeal (e.g., presenting riddles and mysteries) addresses curiosity and fosters interest in the story. The emotional appeal of a comic (e.g., funny comic

figures and dramatic scenes) enables one to build a personal affective connection to the content and thus can foster involvement.

In this line of reasoning, specific story elements such as the comic figures might be of particular importance. The comic figures are usually the actors who drive the story and offer the possibility to build a more personalized emotional connection with the content. Thus, comic figures are essential critical elements for interest and involvement. The involvement and interest in a comic also depend on the subjective preferences of the recipient. On the one hand, general emotional affinities can influence the preference for specific comic elements that, in turn, could affect the reception processes. For example, a person who generally likes dogs might be more involved in the narration if the comic includes a dog as a comic figure. On the other hand, also cognitive affinities should be considered; namely, the so-called need for cognition [7] [8] seems to be an essential person-related variable for the reception of serious comics. Need for cognition can be defined as "the tendency of an individual to engage and enjoy thinking" [7, p. 116]. People with a high need for cognition enjoy thinking and tend to structure the world in a meaningful way. Accordingly, persons with an increased need for cognition might be more interested in a comic that included (also) informative scientific content.

1.2 Overall Research Aim

The overall research aim of this study was the investigation of whether and if so how certain emotional and cognitive affinities influence the reception process of serious comics. Thereby, a particular focus was on the role of the comic figures. As the concrete use case, we operationalized emotional affinity via the general liking for dogs and cognitive affinity via the need for cognition. For emotional affinity, dog lovers (compared to people with a low liking for dogs) should be more interested and involved if one comic figure is a dog. In turn, this could result in a more intense and joyful reading and a better understanding of the scientific content. For the cognitive affinity, persons with a high need for cognition should be more motivated and involved if the story contains science-related content and a scientist (or otherwise experienced academic or wise man) as a comic figure.

In this first pioneering study on serious comics, we used an already existing scientific comic as testing material that provided an appropriate variety of comic figures relating to the emotional and cognitive affinities of the recipients. More specifically, we used an excerpt of the existing scientific comic "Mysteries of the Quantum Universe" by Damour and Burniat [9, pp. 119–123] in which the comic figures are a scientist, a dog, and a non-scientist (who is the owner of the dog). The scientist explains "the paradox of Schrödinger's cat" to the non-scientist. He uses a dog instead of a cat as an illustration for his scientific explanations. Thereby, the scientist is the comic figure most closely related to the scientific content and, thus, addresses foremost the need for cognition. The dog clearly addresses the emotional affinity in the form of the general liking for dogs. Additionally, the dog partly addresses (to a lower degree than the scientist) the person's need for cognition because the dog serves to illustrate the scientific content. The non-scientist just listens to the explanations and, therefore, he addresses neither the emotional affinity (liking for dogs) nor the need for cognition.

1.3 Research Questions and Predictions

This study addressed different research questions (RQ): On the one hand, whether and if so, how are emotional and cognitive affinities, namely the liking for dogs and the need for cognition, associated with favoring a specific comic figure? On the other hand, whether and how the emotional and cognitive affinities or the favored comic figure influence motivational processes like interest and involvement, the understanding of the narration (purely the plot of the comic without the scientific details), and the understanding of its scientific content? In this respect, two different ways of influencing were thinkable. First, the emotional and cognitive affinities could directly affect the motivational and cognitive reception processes (e.g., liking for dogs could heighten the involvement and the scientific understanding). Second, it is also thinkable that the emotional and cognitive affinities are only a general entrance into the comic. In this case, these factors would have no or only a minor direct influence on the reception processes, but they could be the basis for the specific preferences for critical elements of the comic, including the comic figures. Subsequently, the favored comic figure might influence the reception processes in the sense of an all-or-nothing principle. That means, once an individual has decided (based on the emotional and cognitive affinities) which comic figure is the favorite one, the favorite comic figure acts as a focus during the reception of the comic. Accordingly, the favorite comic figure and its closeness to the emotional impact and the scientific explanations should influence the reception processes (including learning). Based on these considerations, we formulated three research questions.

RQ1: Is there an association between emotional and cognitive affinities and the preference for one of the comic figures?

Based on the considerations described above, we made the following predictions about the association between cognitive and emotional affinities and the favorite comic figure:

- The *scientist* addresses the cognitive affinity in the form of the need for cognition because he is the figure who gives scientific explanations and has superior knowledge. Thus, people who favor the scientist should have a higher degree of need for cognition compared to people favoring the dog or the non-scientist.
- The *dog* addresses the emotional affinity in the form of the general liking for dogs. Furthermore, the dog serves to illustrate the scientific explanation and partly addresses the cognitive affinity even though to a lower degree than the scientist. Thus, people who favor the dog should have a higher general liking for dogs than those who favor the scientist or the non-scientist. Additionally, people who favor the dog should have a higher need for cognition compared to those who favor the non-scientist. Still, at a lower level compared to people who favored the scientist.
- The *non-scientist* addresses neither the emotional affinity for dogs nor the cognitive affinity for the scientific content. Thus, people who favor the non-scientist should have a lower degree in need for cognition compared to those who favor the scientist or the dog and a lower general liking for dogs compared to those who favor the dog as a comic figure.

RQ2: Is there a direct association between emotional and cognitive affinities with motivational and cognitive indicators of the comic reception?

If the emotional and cognitive affinities directly affect the reception processes of the comic, there should be the following associations:

- Generally liking the comic and involvement should be positively correlated with the liking for dogs (because one of the comic figures is a dog).
- Generally, liking the comic and the interest in the comic should be positively associated with the need for cognition (because the comic is about a scientific issue).
- Understanding the narration (pure plot without scientific details) should be positively correlated with the liking for dogs and the need for cognition because emotional and cognitive affinities should foster attention and alertness.
- The scientific understanding of the paradox of Schrödinger's cat should be positively correlated with the need for cognition because the scientific content fits this cognitive affinity. For the liking for dogs, there are two possibilities: Either liking for dogs fosters understanding the scientific content (because of a higher personal association with the rather abstract content), or liking for dogs hinders understanding the scientific content because of the cruel animal experiment that distracts from learning.

RQ3: Does the preference for a specific comic figure influence the motivational and cognitive processes of the comic reception?

As mentioned in RQ1, the three comic figures are closely associated with the scientific content but each differently, whereby the scientist has the closest connection, followed by the dog. In contrast, the association of the comic figures with the narration is almost comparable for all three comic figures (three main actors). Aside from that, one might argue that the three comic figures differ in terms of the emotional impact of the story. Since the dog is the object of the very cruel experiment, it has the closest connection to an emotional impact. These considerations lead to the following predictions:

- Involvement should be higher if the dog is the favorite comic figure (because of the closeness of the dog to the emotional impact of the comic).
- The favorite comic figure has no influence on understanding the narration.
- The favorite comic figure influences the scientific understanding of the paradox of Schrödinger's cat, depending on the closeness of the figure with the scientific content: The scientific understanding should be highest if the scientist is the favorite comic figure, followed by the dog. It should be lowest for people who prefer the non-scientist.

2 METHODOLOGY

2.1 Participants and Variables

The data sample comprised 87 participants (33 males, 54 females). Most were university students (81), two were post-graduates, and three had finished high school. The age of the participants was between 18 and 30 (m = 21.84, s = 3.03).

As person-related variables, we measured the participant's emotional affinity (operationalized as the general "liking for dogs") and their cognitive affinity (operationalized as "need for cognition"). As a distinctive comic-related variable, we considered the participant's favorite comic figure (scientist vs. non-scientist vs. dog). We further included the following indicators of the reception process as general comic-related variables:

- Motivational indicators: generally liking the comic, liking the drawings, liking the textual presentation, interest in the story, and involvement.
- Understanding the narration (pure plot without scientific details).
- Scientific understanding (i.e., understanding the scientific content in the form of the paradox of Schrödinger's cat).

Furthermore, we considered the following control variables: prior knowledge in relation to the specific content presented (thought experiment on "Schrödinger's cat"), physics as a special domain and science in general, general affinity to (conventional) comics, general interest in science and physics, general love of animals, fear of dogs, and socio-demographic variables (age, gender, education).

2.2 Procedure and Material

The experimental sessions took place in a calm room of a library. At the very beginning, the participants received brief information about privacy and voluntary participation and signed the informed consent. Before the comic sequence started, we instructed the participants to focus on the content because they would be asked afterward for a summary of the comic sequence and further questions on the presented content. This was to motivate the participants to concentrate not only on the pictures but also on the story with the scientific information.

Afterward, the comic sequence was presented in a computer-based matter. As described above, the testing material was an excerpt from the comic "Geheimnisse der Quantenwelt" [Mysteries of the Quantum Universe] by Damour and Burniat [9] that is a successful (scientific) comic with a fictional story about a historical scientist and accurate scientifically correct explanations and formula on quantum physics. We used a short sequence (described in the introduction) with the explanations of "Schrödinger's cat" [9], starting with the first picture on the left top on page 119 and ending with the first picture on the left top on page 123. Altogether, the sequence contains 24 pictures that were presented as single pictures. The participants proceeded to the next picture by pressing the spacebar. Going back to the previous picture was not possible. Immediately after the presentation of the comic, the participants were asked to answer an online survey that assessed the emotional and cognitive affinities (liking for dogs, need for cognition), the favorite comic figure, indicators of the reception process, as well as the control variables, and some further questions for explorative insights. At the end of the experimental session, there was a short debriefing of the participants, and they were compensated for their participation (5,- €). The study's procedure was approved by the local ethics committee of the German Institute for Adult Education, Bonn.

2.3 Questionnaire

The questionnaire included multiple-choice questions (MC-questions), rating scales, and open questions. For all questions, we used forced answers (i.e., the participants could not skip them) but always provided the option "I don't know" or "no answer". This should ensure that the participants did not forget some answers but still had the freedom to refuse to answer. There was no possibility to go back to prior questions. The questionnaire started with a short welcome and a note about the privacy and anonymity of the data. Subsequently, the motivational indicators were assessed by five questions that had to be answered on a 7-point Likert scale (from 1 = "not at all" to 7 = "very much"). The questions asked how much the participants liked the comic, how much they liked the drawings, how much they liked the textual composition, how much they were interested in the story, and to what extent they felt being involved. The participants were asked which of the three presented comic figures they liked most.

Importantly, the question for the favorite comic figure provided the answering options “tall man”, “small man”, and “dog”. The role of the comic figures as either the scientist (tall man), the non-scientist (small man), and the liked animal (dog) was not explicitly mentioned to avoid demand effects. Afterward, the participants’ understanding of the narration was assessed by a general open question. We also asked (as control variable) whether they had understood the thought experiment on “Schrödinger’s cat” and whether they had already known this thought experiment before the study. Then we assessed the understanding of the scientific content of the comic with four open questions. In addition, we also included seven MC-questions on the narration and on the scientific content. However, the analyses showed that the participants answered nearly all MC-questions correctly; that is, there were clear ceiling effects for the MC-questions on the narration as well as for the MC-questions on understanding the scientific content. Thus, we excluded the MC-questions from the data analyses. The general liking for dogs was assessed by a rating on a 7-point Likert scale (from 1 = “very low” to 7 “very high”). As a control variable, we asked the participants if they were afraid of dogs. In the next section, we measured (as control variables) how much interest and how much prior knowledge in research and science the participants generally had. The analogous questions were asked for physics as a specific domain (rating on a 7-point Likert scale from 1 = “very low” to 7 = “very high”). Further, we also assessed, as a control, how much the participants like conventional comics and what they think about the use of science comics like the one that was presented in the study. Next, we assessed the need for cognition [7]. We used the items of the German short version by Bless and colleagues [10]. The items were formulated as statements, and the participants had to rate how much these statements were true for themselves. For the rating, we used the analogous 7-point Likert scale as for the other rating items in the questionnaire (to avoid confusing the participants). At the end of the questionnaire, we assessed socio-demographic variables (age, gender, education) as further control variables. The analyses of the control variables, namely gender, prior knowledge, interest, and general prior knowledge of physics, as well as a general liking for comics, did not change the pattern of results.

3 RESULTS

3.1 Data Preparation

For most of the assessed variables, we used in the analyses the direct rating (e.g., liking for dogs, liking the comic, interest, involvement) or the nominal answer (e.g., favorite comic figure) of the single items. For the scale on the need for cognition, we calculated for each participant the mean-score across all items.

Answers to the open question on the narration were analyzed in relation to the description of the three comic figures and the description of the story. Depending on the accurateness of the description, the participants received a defined number of points.

The answers to the four open questions on the understanding of the scientific content with respect to the paradox of Schrödinger’s cat were analyzed (analogous to the narration) in relation to a defined list of criteria. For each mentioned criterion that indicated understanding the scientific content, the participant received a defined number of points, depending on the accuracy and exhaustiveness of the answer. For example, if the participant answered (to the open question: “Please explain briefly what Schrödinger wanted to illustrate with his cat-experiment) that the aim of the experiment was “something that has to do with quantum physics”, he/she received only one point. For the more accurate answer “the experiment was to show that quantum physics cannot directly be applied to the macroscopic world”, he/she received three points. For each incorrect criterion mentioned that indicated a deep misunderstanding, the participants received a defined number of negative points, depending on the degree of misunderstanding. For example, for the answer that the experiment was about “how to kill a dog”, the participant received one minus point (because, indeed, it was possible to kill a dog with this experiment, but this was not the aim). The answer “It was about cloning a dog” received five minus points (because it was just a completely wrong confabulation of the two depicted dogs during the explanations given by the scientist). We summed up all attained points for the four open questions on the scientific content and used it as the sum score for scientific understanding.

3.2 Descriptive Analyses

Fifty-five participants had already heard about “Schrödinger’s cat” before, 29 had no prior knowledge. The descriptive analyses of the interval-scaled main variables of the RQs are listed in Table 1.

Table 1. Descriptive statistics of the interval-scaled main variables (liking for dogs, need for cognition, motivational indicators, and the overall score for the open questions on the narration and the scientific content): Number of valid cases (n), mean (m), and standard deviation (s).

Variables	*n*	*m*	*s*
Emotional affinity (Liking for dogs)	86	5.17	1.60
Cognitive affinity (Need for cognition)	71	4.81	0.82
Liking the comic	85	4.86	1.36
Liking the drawings	87	5.29	1.28
Liking the textual presentation	86	5.09	1.27
Interest in the story	87	4.67	1.78
Involvement	83	3.87	1.73
Understanding of the narration	87	9.97	3.53
Scientific understanding	87	7.40	6.84

Most of the participants indicated the dog as the favorite comic character, followed by the non-scientist. The scientist was preferred substantially less often (see Table 2).

Table 2. Frequency distribution of the favorite comic figure and statistical indices of the Chi²-Test: Number of observed cases (Obs) and of expected cases (Exp), and standardized residuals (Std. Res).

Favorite comic figure	*Obs*	*Exp*	*Std. Res*
Scientist	13	28	-2.83
Non-scientist	33	28	0.94
Dog	38	28	1.89
All	84		

The frequency differences (see Table 2) between the favourite comic figures were significant (*Chi²* = 12.500, *p* = .002). The standardized residuals showed that this significant difference traces back to the low frequency of participants who chose the scientist as the favorite comic figure.

3.3 Results on RQ1 – Association between Emotional and Cognitive Affinities and the Favorite Comic Figure

To study the influence of comic figure preference on emotional and cognitive affinity, we calculated separate one-way ANOVAs for emotional affinity and cognitive affinity as dependent measures and favorite comic figure as the independent variable (dog, non-scientist, or the scientist as a favorite comic figure; three levels).

3.3.1 Emotional Affinity: Liking for Dogs

The ANOVA with liking for dogs (7-point rating) as the dependent variable showed a significant effect ($F(2, 80) = 8.939$, $p < .001$, *partial Eta²* = 0.183) for the favourite comic figure. Emotional affinity was the highest if the dog was the favorite comic figure, followed by non-scientist. Participants who preferred the scientist as the comic figure reported the lowest emotional affinity (i.e., liking for dogs, see Table 3). The multiple comparisons of the post-hoc test (Scheffé test) showed a significant difference between the participants who favored the dog versus the non-scientist ($p = .002$, *95% CI* [0.40, 2.12]). Also, the difference between those who favored the dog versus the scientist was significant ($p = .007$, *95% CI* [0.34, 2.63]). However, the difference between the participants who favored the scientist versus the non-scientist was not significant ($p = 0.891$, *95% CI* [-1.4, 0.95]). To sum up, the participants who indicated the dog as their favorite comic figure showed a significantly higher general liking for dogs.

Table 3. Descriptive statistics for generally liking dogs for the subgroups of participants who indicated the scientist, the non-scientist, or the dog as their favorite comic figure:

Favorite comic figure	n	m	s
Scientist	13	4.46	1.33
Non-scientist	32	4.69	1.73
Dog	38	5.95	1.16
All	83	5.23	1.56

Number of valid cases (n), mean (m), and standard deviation (s).

3.3.2 Cognitive Affinity: the Need for Cognition

The ANOVA with need for cognition (7-point rating) as the dependent variable showed also a significant effect for the favourite comic figure ($F(2, 66) = 4.693$, $p = .012$, *partial Eta²* = 0.125). The participants who favored the scientist showed the highest need for cognition, followed by those who favored the dog. The participants who favor the non-scientist showed the lowest need for cognition (see Table 4).

Table 4. Descriptive statistics for the need for cognition for the subgroups of participants who indicated the scientist, the non-scientist, or the dog as their favorite comic figure.

Favorite comic figure	n	m	s
Scientist	12	5.44	0.59
Non-scientist	28	4.66	0.73
Dog	29	4.73	0.88
All	69	4.82	0.82

Number of valid cases (n), mean (m), and standard deviation (s).

The multiple comparisons showed that the difference between participants who favored the scientist versus the non-scientist was significant ($p = .017$, *95% CI* [0.12, 1.46]). Also, the difference between the scientist versus the dog was significant ($p = .033$, *95% CI* [0.48, 1.38]). The difference between participants who favored the dog versus those who favored the non-scientist was not significant ($p = .940$, *95% CI* [-0.44, 0.59]). Taken together, the participants who favored the scientist showed a significantly higher need for cognition.

Overall, the findings on RQ1 are in line with our predictions. The data indicate a clear association between the emotional and cognitive affinities and the preference for one of the comic figures. The emotional affinity in the form of the general liking for dogs was associated with a preference for the dog as the comic figure, and the cognitive affinity in the form of the need for cognition was associated with the preference for the scientist. Also, we find weak (but not statistically significant) evidence for the gradual predictions made for RQ1 in relation to the quantitative ranking of the three comic figures, depending on the participants' emotional and cognitive affinities.

3.4 Results on RQ2 – Association between Emotional and Cognitive Affinities and the Indicators of the Reception Process

Overall, neither liking for dogs nor need for cognition were directly associated with the different motivational and cognitive indicators of the reception process with one exception in the form of a significant correlation ($r(80) = .284$, $p = .01$) between liking for dogs and involvement, indicating that people who like dogs more were more involved in the story. The understanding of the narration and the scientific content was not associated with the emotional and cognitive affinities.

In relation to RQ2, our results contradicted the predictions made; that is, we found no significant associations between the emotional and cognitive affinities and the indicators of the reception process.

3.5 Results on RQ3 – Influence of the Favorite Comic Figure on the Indicators of the Reception Process

For the influence of the favourite comic figure on the variables of the reception process, we calculated a MANOVA for the motivational indicators (liking the comic, liking drawings, liking textual presentation, interest in the story, and involvement) because there were significant correlations between the five motivational indicators. For the understanding of the narration and for scientific understanding as the dependent variables, we calculated separate ANOVAs. The descriptive statistics are listed in Table 5.

Table 5. Descriptive statistics for the dependent variables (motivational indicators, understanding of the narration, and scientific understanding) for the subgroups of participants who indicated the scientist, the non-scientist, or the dog as their favorite comic figure.

Variable	*Subgroup*	*n*	*m*	*s*
Liking the comic	Scientist	13	5.46	1.39
	Non-scientist	32	4.69	1.36
	Dog	32	4.78	1.31
	All	77	4.86	1.35
Liking drawings	Scientist	13	5.54	1.39
	Non-scientist	32	5.47	1.19
	Dog	32	5.06	1.32
	All	77	5.31	1.28
Liking textual presentation	Scientist	13	5.38	1.39
	Non-scientist	32	5.22	1.10
	Dog	32	4.78	1.31
	All	77	5.06	1.25
Interest in the story	Scientist	13	5.38	1.76
	Non-scientist	32	4.44	1.85
	Dog	32	4.59	1.70
	All	77	4.66	1.78
Involvement	Scientist	13	4.31	1.55
	Non-scientist	32	3.53	1.65
	Dog	32	4.03	1.82
	All	77	3.87	1.71
Understanding narration	Scientist	13	9.15	3.98
	Non-scientist	33	10.33	3.34
	Dog	38	10.34	3.36
	All	84	10.15	3.44
Scientific understanding	Scientist	13	11.00	7.90
	Non-scientist	33	5.27	6.52
	Dog	38	8.13	6.51
	All	84	7.45	6.95

Number of valid cases (n), mean (m), and standard deviation (s).

The MANOVA for the factor “favorite comic figure” showed no significant effects for the motivational indicators as dependent variables. Also, the ANOVA with the understanding of the narration as the dependent variable showed no significant effect for the factor “favorite comic figure” ($F(2, 81) = 0.646$, $p = .527$, *partial Eta²* = 0.016). However, the ANOVA for the understanding of the scientific content as the dependent variable showed a significant effect ($F(2, 81) = 3.72$, $p = .028$, *partial Eta²* = 0.084) for the favorite comic figure. The participants who favored the scientist reached the highest sum score for understanding the scientific content, followed by those who favor the dog. The participants who favor the non-scientist had the lowest sum score for scientific understanding. The multiple comparisons of the

post-hoc test showed that the difference between the participants who favored the scientist versus the non-scientist was significant (p = .039, *95% CI* [0.23, 11.23]). The comparisons between participants who favored the scientist versus the dog (p = .42, *95% CI* [-2.53, 8.27]) and between participants who favored the dog versus the non-scientist (p = .21, *95% CI* [-1.14, 6.86]) were not significant.

The results on RQ3 provided only partial support for the predictions made. We found no significant influence of the preference for one comic figure on the motivational indicators or the understanding of the narration. However, the scientific understanding was significantly higher if people favored the scientist compared to the non-scientist. Also, there was weak (not significant) evidence for the predictions made for the ranking between the scientist, the dog, and the non-scientist as the favorite comic figure.

4 DISCUSSION AND CONCLUSIONS

In the present study, we empirically explored central aspects of the "serious comics" approach [2]. The results are important for the development of a comprehensive account of how comics contribute to learning and knowledge acquisition [11]. More specifically, our results provided a rather clear pattern of answers to the three RQs that we derived from the literature. First, our data showed that the favorite comic figure reflected the emotional and cognitive affinities of a person. The results were in line with the predictions made in RQ1. The participants who generally like dogs also favored the dog as a comic figure. Analogous, the participants with a high need for cognition favored the scientist as a comic figure. Thus, the emotional and cognitive affinities of a person shape his/her preferences in relation to the favorite comic figure. Interestingly, the emotional and cognitive affinities were not associated with learning success or with the motivational indicators. These findings clearly contradicted the predictions made in RQ2. The only exception was the association between the general liking for dogs and involvement. At first sight, it seems rather trivial that people who generally like dogs are more involved in a story about the fate of a dog. On the other hand, it is interesting enough that only involvement showed an association with the emotional affinity of the recipient, but not the other motivational indicators. One explanation could be that involvement has a special role, in contrast, to simply liking the comic or the graphics, because involvement was the most global motivational indicator in our study and is often seen as the key to entertainment. Most remarkable were the findings for RQ3 with respect to the influence of the favorite comic figure on the indicators of the reception process. While there was no effect of the favorite comic figure on involvement or the understanding of the narration, we observed a significant effect of the favorite comic figure on scientific understanding; namely, if the favorite comic figure was more closely connected with the scientific explanations, the participants showed a better scientific understanding.

To sum up, the answers to our RQs were as follows: First, we had a clear association between the emotional and cognitive affinities of the recipients and their favorite comic figure. Second, there was no general direct association between the emotional and cognitive affinities and the indicators of the reception process. Only involvement – as the most global indicator and a key factor of enjoyment – showed a significant connection with emotional affinity. Third, the favored comic figure had a decisional role in the understanding of the scientific content. Taking this pattern of findings together, it seems that the emotional and cognitive affinities of the recipients are a kind of general entrance into the comic that relates foremost to the preference for one of the comic figures. Additionally, the general involvement shows a significant association with the emotional affinity of the recipient. However, in relation to scientific understanding, it is not the emotional and cognitive affinities but the favorite comic figure that plays a central role. The closer the comic figure is connected with the scientific content, the better the scientific understanding will be. Accordingly, the favorite comic figure might bundle the attention and cognitive resources of the recipient. Another explanation could be that identifying with the favorite comic figures provides a biographic-like experience that causes a deeper understanding.

Our study does have certain limitations. Primarily, we used existing material that was appropriate for obtaining sound insights, but the comic figures were not systematically varied in relation to our research questions. Thus, the findings must be handled with care because it could be that also other characteristics of the comic figures (besides their roles as dog, scientist, and non-scientist) might have been the influencing factors, for example, the appearance of the comic figures. Additionally, our questionnaire should be improved for future studies and should include also a rating on how much the participants liked the figures. Such a rating could give more detailed insights into the degree of influence. As statistical limitation we had unequal group sizes for the favorite comic figure, and in the face of the rather small sample, the findings must be interpreted with caution. Finally, we used an artificial setting,

i.e. presenting picture after picture on a computer screen without the possibility to go backward. Thus, the generalization to a realistic reading situation is limited.

Our study provides first insights into the influence of specific design features of serious comics, namely the comic figures and the influence of the emotional and cognitive affinities of the recipient. It becomes clear that comic figures are an essential key to learning success and scientific understanding with serious comics. On the one hand, the comic figures should be created in a way that matches the emotional and cognitive affinities of the recipient. On the other hand, the role of the comic figures in the story should be closely related to the explained scientific content. Future studies should address the underlying mechanisms and should measure the focus of the recipient's attention and the degree of identification with the favorite comic figure. Additionally, it would be interesting to know how fast the preference for one of the comic figures develops. Overall, our study shows that systematic investigations on the design of serious comics can provide the basis for an optimized design that also allows for science communication of complex themes. We hope this study also inspires other researchers to look for the full potential of serious comics.

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