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Replicating a study about children's drawings concerning radiation

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Abstract
Radiation surrounds us in various forms and plays a huge role in our everyday life. However, little is known about student and children's conceptions of this topic. This study is part continuation part replication of the studies carried out by Neumann and Hopf (2013). The method employed in both studies was identical. 459 students drew pictures associated with the concept "radiation" under observation. The resulting motives were subsequently categorized and compared. In this study the children barely associate the concept of "radiation" with the Fukushima Nuclear Disaster. Moreover, a number of differences could be realized when compared to the reference study. For instance, significantly more students drew cell phones and computer monitors in the current study. Additionally, a greater number of drawings related to radioactivity could be observed. Overall, the findings of this work indicate that not only are students exposed to the media at a much younger age, but also more frequently. This leads to the conclusion that more and more children build their own understanding of a particular subject, which could potentially result in misconceptions.

Keywords
Radiation, children drawings, replication study, Fukushima, radioactivity

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1. Introduction

Students' conceptions about radiation are a field of little interest in empirical science education research. However, this topic influences our everyday life on a broad basis. From mobile phone radiation to X-rays in medicine we are surrounded by radiation every day. Neumann and Hopf (2013) investigated the drawings of over 500 children to answer the question, what motifs are drawn and do these motifs change over time? This study replicates the study by Neumann and Hopf and expands the question. After five years the topic of radiation and Fukushima has disappeared from the media. Therefore it is interesting to find out if the increase of motifs related to radioactivity documented by Neumann and Hopf is visible today. Makel and Plucker (2014) stated the importance of replication studies in education research. They point out the fact, that only 0,13% of all published studies are replication studies. Replication studies have the potential to "identify, diagnose, and minimize many of the methodological biases (Makel and Plucker p. 305)". There are many ways to design a replication study (for a good overview, see Schmidt 2009). In our replication study we use the same design and method to analyze the drawings. We also tried to investigate children from the same schools to enable a good comparison. Additional children from a rural area were part of this study to compare them to children from the city.

2. Previous findings

Many studies in the mid-nineties (H. Eijkelhof and Millar 1988; H.M.C. Eijkelhof 1996; H. M. C. Eijkelhof et al. 1990; Lijnse et al. 1990; Millar et al. 1990; Millar 1994; Millar and Gill 1996) revealed frequent misconceptions (false conceptions) on nuclear radiation. They documented problems with the concept of contamination and irradiation or the concept of activation: an object emits radiation after being exposed to radiation. Additionally, students linked the effects of nuclear radiation to other environmental issues like the greenhouse effect or the ozone layer. A lot of these misconceptions can be found

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today. Sesen and Ince (2010) reported in their study that those misconceptions are widely spread on the Internet. This source for students to learn can stabilize their misconceptions.

Other studies focusing on invisible radiation as distinct from nuclear radiation came up with very concerning results. Rego and Peralta (2006) found that students were unable to distinguish between non-ionizing and ionizing radiation. Most of the students could not tell the difference between various types of radiation. Libarkin et al. (2011) focused on infrared (IR) and ultraviolet (UV) radiation. The majority of students (age 10 to 16) believed that the sun is the only origin for UV-radiation. They also described UV as "light," "bright light," "strong rays," "very violet," "a color like red, blue, purple light," or "harmful rays." Concerning IR-radiation a lack of knowledge was revealed; scarcely anybody had heard of this kind of radiation.

Plotz (2017) summarized conceptions of nuclear radiation and various types of electromagnetic radiation. He provides a recent overview of the excising literature. A lot of the mentioned studies dealt with misconceptions and associations linked with radiation. Overall we see a nonpoint picture of the students' conceptions. There is a clear gap in the knowledge of students' conceptions in the field of radiation.

Due to the design of this study, the most important findings are those of Neumann and Hopf (2013). They showed first and foremost, that children are likely to draw the sun, when they are asked to draw about radiation. About 70 percent of the students drew a picture of the sun or sunlight. Overall, Neumann and Hopf showed, that the motifs are often connected to visible light and to sources of radiation like mobile phones and monitors. There was also a shift in motifs from younger (sun, visible light) to older children (artificial light sources). In addition to the first study 2009 Neumann and Hopf (2011, 2012), also investigated the change in motifs in 2011 after the nuclear accident in Fukushima. In figure 1, this change in percentage of motifs is visible. Neumann and Hopf documented a significant change in the motifs connected to radioactivity.

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ISSN: 2341-2593

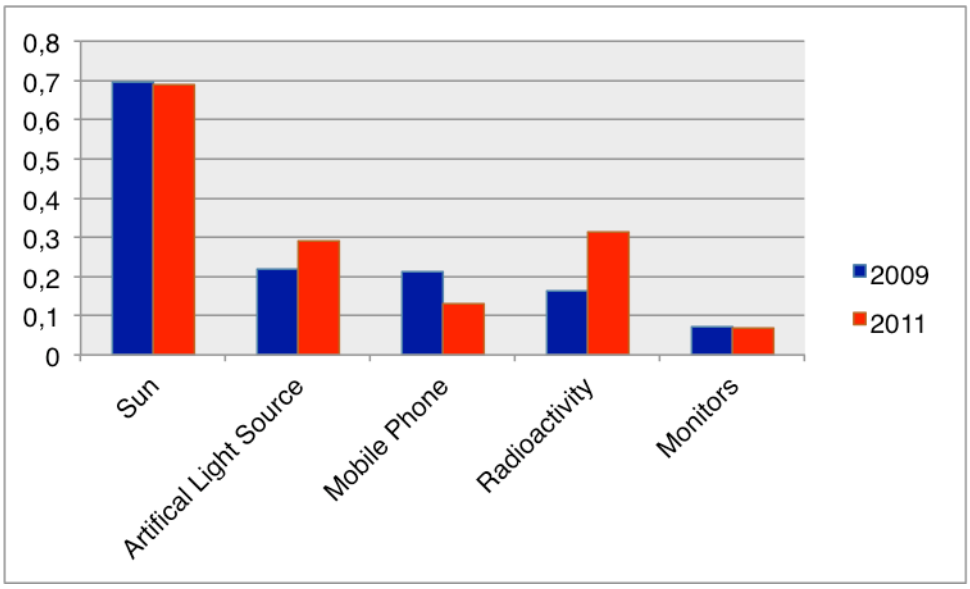

Figure 1. Results according to Neumann and Hopf (2013)

They explained the change with the enormous amount of coverage of the accident in Fukushima in the media. This connection has been documented in the drawings and in interviews with the students after they drew the first set of pictures. They also saw a significant increase of the motifs related to visible light sources and a significant decrease in the pictures of mobile phones. Both changes were not explained in the study. As mentioned above, there is a limited set of known conceptions concerning radiation.

3. Research method

The method of drawing associations is used to identify students' perception of the concept "radiation". Students are asked to draw pictures associated with the subject under consideration. In general, this method originated in the psychological field in the middle of the 19th century. There it was used to get some impression of the psychological state of children, to get a "window into his/her thoughts and feelings". Later on it was believed, that drawings of children could tell us something about their intelligence. This

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assumption did not prove right and was dismissed. However, the idea that children's drawings could provide information about their understanding of a particular concept proved fruitful and was further examined.

In natural sciences, this technique was already used by Chambers (1983) between 1966 and 1977 in his famous "Draw-a-scientist Test". In this test children had to draw a picture of what they believed a scientist looked like. White and Gunstone (1992) also used this methodology to investigate processes of understanding. Children were asked to draw a teacher while he is teaching, at the beginning of the school year. Most of the drawings showed conventional teaching sequences, where a teacher stands in front of the class and children sit in rows facing him. At the end of the year those school students were asked to repeat the exercise. The resulting drawings looked quite different, as this year the children were taught in a very open way and the pictures reflected that. They showed a lot of mixed class structures, where for example a lot of teamwork sessions without teachers could be seen. Dikmenli (2010) used this method to discover perceptions concerning cell division. Rennie and Jarvis (1995) investigated what children understood under the term "Technology". The following picture (figure 2) makes clear, that the results of Rennie and Jarvis (1995) are comparable to the drawings of this study. In both studies the children had to draw pictures of abstract concepts or terms.

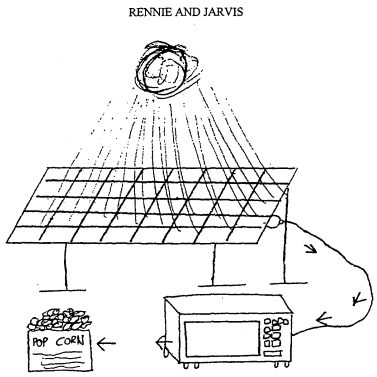

Figure 2. A Year 6 boy's drawing (Rennie and Jarvis 1995, p.246)

https://doi.org/10.4995/muse.2019.10390
ISSN: 2341-2593

In general, this method has a lot of advantages, as well as a number of disadvantages. Its biggest advantage is that it turns out to be ideal to examine concepts of progresses inherited by students. Dove et al. (1999) used it in their study of children between the age of nine and eleven, who were asked to draw a water cycle. It turned out, that most of the proponents did not know where a river starts, however they did know where it ends. Most of the time, rivers were drawn flowing from left to right. All this information probably would not have been observed with, for instance, interviews. Another advantage of this method is that it is very open. Questionnaires, especially multiple-choice tests have a lot of limiting factors, which limit the forms of expression of the proponents. On the other hand, questionnaires are far easier to interpret than drawings.

This leads to one of the biggest problems of this method. It is very difficult to interpret drawings. The statement that drawings enable us to look into the "heads" of children is an assumption, not a fact. It must also be considered, that drawing is not an easy exercise for children. They need to have certain cognitive skills and it could happen that they are faced with "organizational and procedural problems". For example, (Brown et al. 1987) asked children to draw pictures of what they associated with nuclear power plants. No human beings could be observed around the power plants in most of the drawings. The reason for that was not that they did not imagine any people in that environment. It is very difficult for school students to draw humans and so the children avoided that task. In addition to that, children between the age of nine and ten start to criticize their drawings. It is frustrating to them, when a drawn object does not look like the real one. Last but not least, the common education systems lack the facilitation of drawing skills. From the age of six to ten school children still draw a lot but then at each step up the education ladder this skill is replaced by writing and reading.

In summary, this method gets more and more impractical as students get older. Nevertheless sometimes emotions of students are revealed through a drawing. There are examples where the picture shows happy children in the sun. Other one, obviously

https://doi.org/10.4995/muse.2019.10390
ISSN: 2341-2593

associated power plants with negative feelings because the look at the face of the person is sab. In general, the method is useful with younger children. It is real fun and therefore motivates students to participate. Thomas and Silk (1990) wrote, „children make drawings largely for the satisfaction they get from the activity". Nearly every tested class welcomed the diversion from writing and reading. It seemed that the task had even a relaxing effect for most of the children.

In conclusion, the method is highly underestimated in its values to examine conceptions of children. However, it must be considered, that its usefulness depends on the subject under consideration and the age of students. Currently a study is being carried out, testing this technique with older children (age 16 to 18) on the subject of radiation.

We implemented the procedure described by Neumann and Hopf to collect drawings from the students. The students received a blank sheet of paper and the word "Strahlung" (the German word for radiation, as used in the term "elektromagnetische Strahlung") was written on the board in the classroom. We or the teacher asked the students to draw whatever comes to their minds, whenever they read or hear the word. During the period of drawing, the teacher did not answer any subject-specific questions and the students were encouraged to draw any motif. After 10 to 15 minutes the drawings were collected. To analyse the drawings, we categorised the motifs using the five main categories from Neumann and Hopf.

- The sun
- Artificial source of light (lamps, flashlight, …)
- Motifs related to radioactivity (nuclear power plants, radioactive warning sign…)
- Mobile phones
- Monitors (all types of different screens like, TV, computer or laptop)

In addition to these categories, we found new motifs, which we grouped into several side categories.

https://doi.org/10.4995/muse.2019.10390
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In this study, we collected drawings from 459 students (age 9 to age 12) from seven different schools in Austria. Three schools are located in Vienna and four schools are in the countryside of Upper-Austria. The drawings were made and collected in December 2015. As shown in figure 4 the process of data collection was done four years after the second and six years after the first study. To be able to compare our data to the previous study of Neumann and Hopf we decided to collect drawings in two schools from their study (both in Vienna).

Table 1. Qverview of the collected sample.

2015	town	countryside	total
4th grade	54	39	93
5th grade	68	109	177
6th grade	45	144	189
total	167	292	459

To conclude the setting of the replication study was as similar to the original study as possible to be able to compare the numbers. However, there was a major change in the data collection process. We did not differentiate the gender of the students. This decision was based on the fact that the results did not vary significantly for most categories in the original study. We focused more on the overall numbers and the variation between the different age and location of our students. We addressed the following research questions.

https://doi.org/10.4995/muse.2019.10390
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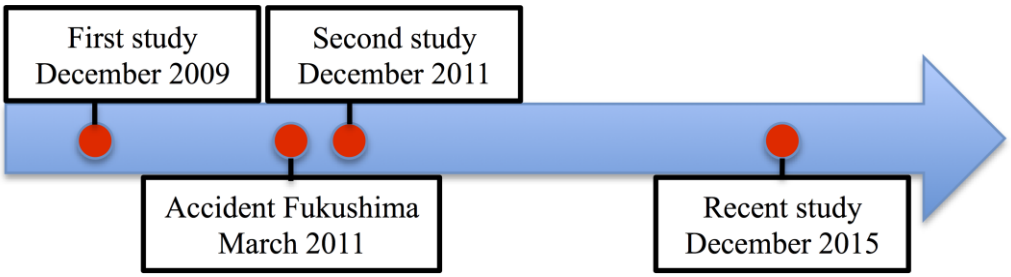

Figure 3. Timeline of the different studies

3.1 Research questions

Due to the fact that this study is a replication study, the most important research question is if the results are the same as in the study of Neumann and Hopf (2013). Therefore the first two research questions match the questions from the previous study.

- What do younger students (age 9 to 12) associate with the term "radiation"?
- Do these associations change with the age of the students?

The fatal accident in Fukushima occurred in March 2011. Since then the attention in the media has vanished. Neumann and Hopf (2013) assume in their discussion that media (newspaper, TV) and the discussions in school caused the increase of motifs related to radioactivity. Hence, we formulate the hypothesis that the number of associations with radioactivity should decrease to the level of 2009.

In addition to the questions above, we investigated two research questions.

- Do students from the countryside associate other motifs than students from the city?
- Are there other motifs in our drawings beside the main categories?

https://doi.org/10.4995/muse.2019.10390
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4. Results

First we compared the overall numbers with the results of the study from Neumann and Hopf (2013). In Figure 4, the results are shown for the five main categories. The percentage of drawings picturing the sun ($\chi 2=1.145$, df=1, $p<0.01$) and radioactivity

($\chi 2=1.317$, df=1, $p<0.01$) has not changed in a significant way, compared to 2011. What stands out is the vast increase of pictures of mobile phones ($\chi 2=38.1$, df=1, $p<0.01$) and monitors ($\chi 2=30.99$, df=1, $p<0.01$). Both doubled the percentage from 2011 to 2015. We assume, that the different accessibility to mobile phones and computers are the main reasons for this increase.

Our hypothesis, that the increase in radioactive motifs from 2009 to 2011 should vanish, can be rejected, due to the slight but not significant increase in the percentage (to about 35%). We can also see a significant increase of pictures containing artificial light sources ($\chi 2=12,11$, df=1, $p<0.01$).

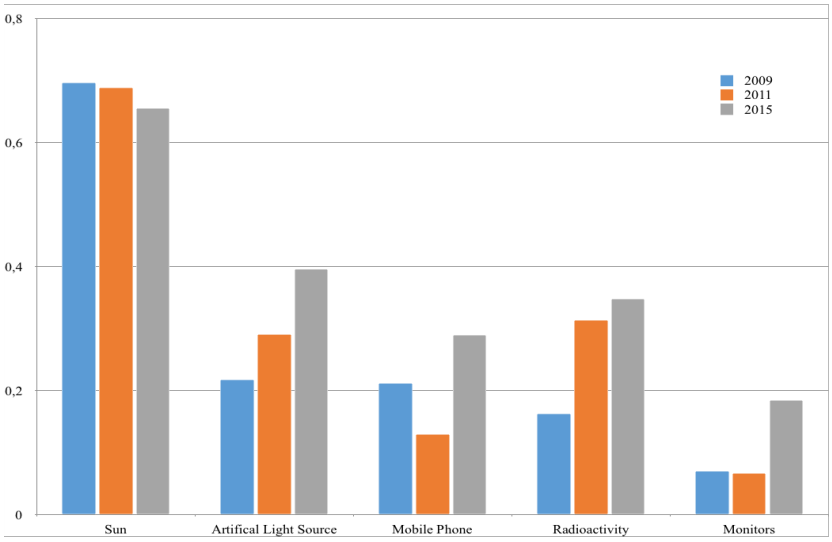

Figure 4. Comparison of the five main categories

https://doi.org/10.4995/muse.2019.10390
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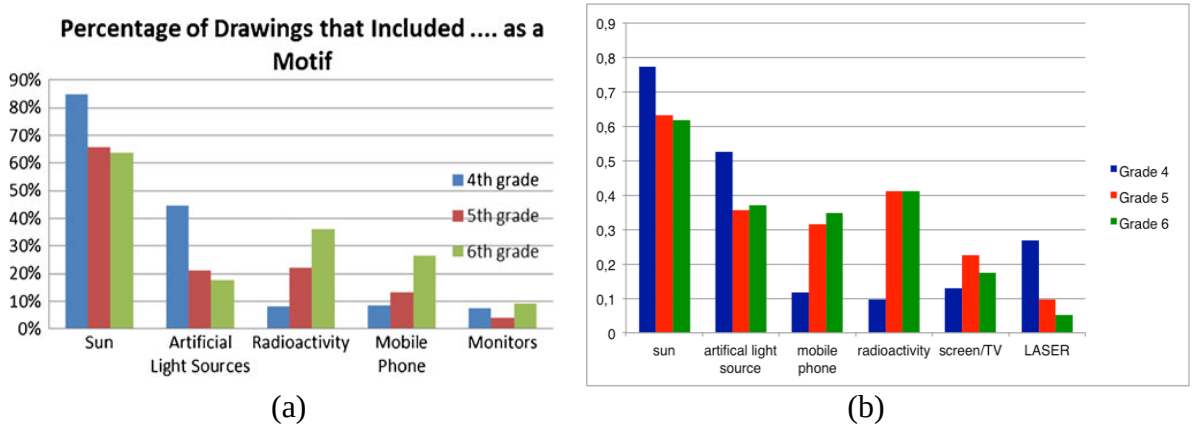
To investigate the second question further, we ordered the appearance of different motifs to the different grades. We can observe a very similar trend to Neumann and Hopf (see also figure 5).



(a) (b)

Figure 5. percentage of motifs from Neumann Hopf 2013 (a) and from actual study (b)

There is a decrease in motifs showing the sun and artificial light sources. For both motifs we see a significant drop-off between grade four and five. For the sun we have $\chi 2=5,68$, df=1, $p<0.05$ and for artificial light source the calculated $\chi 2$ is $\chi 2=7,34$, df=1, $p<0.05$. Looking to the other categories, a increase in the frequency of the appearance of mobile phone, radioactivity and monitors in various forms can be seen. In the categories mobile phone and radioactivity there is a clear significant jump from grade four and grade five. However, the difference between grade five and grade six is not significant for the first four categories.

There is an interesting new finding in the comparison of the different grades. In our analyses we found a decent amount of pictures depicting LASER in various forms. These motifs are new and were not documented before. They appeared on 11,3% of the drawings in all grades. However, there was a difference in the grades. The younger children drew the motif more often (27%) than the older one (5% in grade 6).

https://doi.org/10.4995/muse.2019.10390
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In addition to the appearance of LASER-themed drawings we identified two interesting subcategories. Neumann and Hopf found, that the vast majority (81,4%) of the drawings related to nuclear radiation had a negative connotation, especially after the accident in Fukushima. They even pointed out that only three drawings showed positive aspects of radioactivity. Although our results showed a similar amount of drawings related to radioactivity, we also found in 13,7% of our drawings positive aspects related to radioactivity or radiation in general. There are different examples for this in the drawings like a smiling worker in a power plant or a smiling person in a "radiation chamber".

The second subcategory we called the etymology category. To fit into this category the motifs should contain a connection to the word radiation or radiate. One example for those motifs was a picture of a smiling face. The German language normally uses the term "to radiate with joy" instead of "to beam with joy". So therefore there is a connection for the children to the word radiation. The same argument can explain the appearance of the number line in some drawings. The German translation would be "Zahlenstrahl" ("number ray"). We found those motifs in about 4,1% of our drawings.

The comparison of the students from the schools in Vienna to their colleagues in the countryside can be seen in figure 6. There is no significant difference between those two groups in the two main categories sun and artificial light source.

https://doi.org/10.4995/muse.2019.10390
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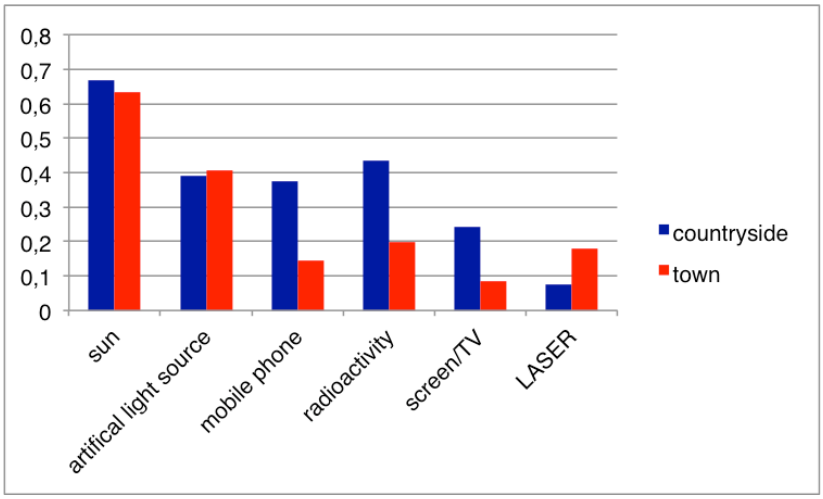

Figure 6. comparison of the main categories town/countryside

In the main categories mobile phone ($\chi 2=27,21$, df=1, $p<0.01$), radioactivity ($\chi 2=26,34$, df=1, $p<0.01$) and monitors/screens ($\chi 2=17,88$, df=1, $p<0.01$) there is a significant difference. In all of those categories the students from the countryside drew the motifs more often. The subcategory LASER shows that the difference is the other way round ($\chi 2=11,5$, df=1, $p<0.01$).

that the proposed methodology is on the way of being introduced right now, as the subject is taught this year for the first time (academic year 2012-2013), and during the spring semester. Consequently, the results that will be presented and discussed will be, up to now, incomplete. Finally some observations, which seem to show some disadvantages or difficulties that may appear during the evaluation process, together with some proposals to overcome them, will be mentioned.

https://doi.org/10.4995/muse.2019.10390
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5. Discussion and conclusion

Looking into the results there is not much of a connection to the nuclear disaster of Fukushima. The slight increase in the radioactivity category occurred because of the pictures of applications like cancer treatment that were linked to nuclear radiation. Overall, the results correspond with the previous study and the overall trend in the appearance of the different motifs, although there are some interesting exceptions, like the picture of lasers from above. At the time of the data collection the new Star Wars film (The awakening of the force) premiered and laser swords were part of the everyday life of the students. Therefore it is reasonable to link the appearance of this topic relate to radiation in the media to the frequency of the pictures of this topic in our research. This link is also a possible explanation for the increase of motifs for radioactivity in the original study. Neumann and Hopf hinted this link in their discussion as they wrote:

„The analysis of the interviews reinforced our hypothesis that the reason for this change in the students' associations could be found in the tragic events of Fukushima." (Neumann and Hopf 2013)

However, we are not able to explain the result that in 2015 the frequency of radioactive motifs is as high as in 2011. The media coverage has rapidly decreased in the years after 2011 and so there should be a decrease. The results did not show much of a connection to the nuclear disaster of Fukushima. The slight increase in the radioactivity category maybe occurred, because of pictures of applications like cancer treatment that were linked to nuclear radiation. We think that this point should be investigated further in the future. The initial hypotheses that the frequency of motifs related to radioactivity should decrease could not be confirmed. The increase in the initial study can therefore not be linked easily to the media coverage.

In our analyses we found pictures with smiling faces or the number ray and we decided to put these motifs into a new category. We called it the etymology category. Neumann and Hopf also discussed the impact of the language to their results.

https://doi.org/10.4995/muse.2019.10390
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"We assume that these results are strongly influenced by the German language since the German word Strahlung (radiation) is commonly used in everyday speech, especially in connection with the word ‚sun'". (Neumann and Hopf 2013)

In a similar fashion knowledge of the German language is necessary, to understand the connection between a smile and radiation. The phrase "A shining smile" means, the face is radiating in German. And the "Zahlenstrahl" contains the word "Strahl" which can be translated with 'ray'. Keeping those explanations in mind it seems obvious, that further research is necessary. Therefore we plan to conduct a study in different European countries (Denmark, Italy, France,…) to validate the hypotheses that there are certain motifs depending on the language and others that are independent thereof (for example the motif of the sun). Due to the very simple instruction to the students the collected data should be comparable and we hope to get a better insight into the conceptions of children concerning radiation.

New are the results from the comparison between the drawings of children living in a town to those living in the countryside. It is interesting, that there is a significant difference in three of the five main categories. In addition to these three there is an inverse difference in the LASER-motif. There is no good explanation for this result.

Overall we think, that this study helped to solidify some results from the original study. It also showed the importance of replication studies. Therefore we strongly recommend, that more replication studies should be conducted. We also see a possibility and a necessity to investigate this topic further.

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