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Promises and Pitfalls: Taking a Closer Look at How Interactive Infographics Affect Learning From News

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This study investigates how interactive infographics affect individuals' understanding of news. We conducted a survey experiment (*N* = 293) to isolate the effects of a clickable graph and a slider graph on memory of the interactive graphical content and the surrounding text-based content, respectively. Moreover, to shed light on the underlying mechanisms linking interactive infographics with individuals' cognitive responses en route to learning, we test a model with interface assessment, absorption, and elaboration as key mediators of information acquisition. Overall, the findings point to a negative impact of interactive infographics on news consumers' memory. However, allowing users to interact with information displayed in graphics cannot be expected to uniformly affect the learning process; instead, the impact of interactive visual content depends on how the use of specific interactive modalities initiates both affective and cognitive processes in audiences when reading online news.

Keywords: experiment, infographics, interactivity, learning, online news

In the first decades of the 21st century, interactive infographics are regarded as the cutting edge of information design (Loosen, Reimer, & De Silva-Schmidt, 2020). Media practitioners assume that they attract audiences' initial attention and convey information in a clear and concise manner that improves the ability to understand and remember complex issues and events (Dick, 2014; George-Palilonis, 2017). Empirical findings, however, are mixed (Bussemas, 2018; Lee & Kim, 2016; Wojdynski, 2015), and despite their ever-growing popularity, we are still at the beginning of understanding whether and how interactive infographics facilitate individuals' acquisition of news. In particular, while studies consistently confirm the affective function of interactive visualizations in terms of readers' situational interest, enjoyment, and appeal (de Haan, Kruikemeier, Lecheler, Smit, & van der Nat, 2018; Kennedy & Hill, 2018), empirical evidence of their cognitive function, such as the mental activities of processing, storing, and recalling content (Neisser, 2014), is scarce (Yang & Shen, 2019).

The limited understanding of the role that interactive infographics play in the process of learning from news might be attributed to two shortcomings in previous research. First, most existing literature on interactive

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infographics does not go beyond a simple distinction between interactive and noninteractive presentation forms, inhibiting a more nuanced perspective on the various interaction modalities employed in contemporary online news environments. In a seminal examination of six different on-screen interaction techniques, Sundar, Bellur, Oh, Xu, and Jia (2014) demonstrated that clicking, sliding, dragging, flipping, hovering, and zooming afford distinct types of user actions and that even minor variations in individuals' behavioral engagement with an interface have significant psychological implications for message processing. Second, until now, interactive visual elements have mostly been conceptualized as global features, affecting memory of all parts of a message equally (Bussemas, 2018; Lee & Kim, 2016; but see Xu & Sundar, 2016). Infographics in traditional online news stories, however, are usually embedded in a noninteractive text. Although visual elements are important entry points into a news story (Holsanova, Rahm, & Holmqvist, 2006), overall, users are primarily focusing on the text (de Haan et al., 2018; Haßler, Maurer, & Oschatz, 2019). Potential spillover effects of interactivity on the comprehension of the surrounding text are therefore important to investigate.

The present study addresses these two gaps by providing a more careful differentiation of both the independent and the dependent variable. In particular, we (1) systematically test the effectiveness of two methods of interaction offered by infographics (i.e., affording clicking or sliding) when embedded in a news article on climate change and (2) distinguish between learning from interactive graphical content and learning from surrounding text-based content. Moreover, to shed light on the underlying mechanisms linking interactive infographics with individuals' cognitive responses en route to learning, we test a model with interface assessment, absorption, and elaboration as key mediators of information acquisition (Oh & Sundar, 2015; van Noort, Voorveld, & van Reijmersdal, 2012). In doing so, we provide a comprehensive view of how news consumers respond to and might benefit from interactive infographics, which is an increasingly important tool to convey complex issues in online news.

Cognitive Responses to Interactive Infographics

Infographics published in online media are hybrid forms of communication that integrate images, text, numbers, visual design, and Web technology to provide a visual explanation of complex phenomena (Weber, 2017). They aim to transform unstructured information into graphical compositions that are both easy to understand and visually appealing (Barnes, 2017). The actual design of the graphics can vary greatly, as demonstrated, for example, by the annual Malofiej awards ("17 Gold Medals," 2020). In all cases, infographics are considered interactive when the user is offered at least one option to modify the form or content of the graphic in real time (McMillan, 2006; Steuer, 1992). In this sense, interactivity is treated as an attribute of the technology, referring to the variety of functional tools available on an interface that allow users to engage with information ("modality interactivity"; Sundar, 2007, p. 90). These tools are considered behavioral affordances (Norman, 1988), which are "perceivable properties of a system suggesting ways in which it could be operated" (Sundar, Jia, Waddell, & Huang, 2015, p. 50). Besides technological properties of the medium, interactivity manifests in aspects of the communicative context and in user perceptions (Kiousis, 2002). Hence, it is the user who releases the interactive potential of an interface by responding to its underlying programming in a particular way (Weber, 2017). Consequently, in this study, interactive infographics are understood as enabling users to perform actions that induce changes in the system, which may in turn lead to changes in the user (Domagk, Schwartz, & Plass, 2010). Because the focus of this study is on the effects of different methods of interactivity offered by an infographic, we place our study within the framework of modality interactivity (see

Sundar et al., 2014, for a similar conceptualization). However, clicking on hyperlinks might be perceived as an interdependent exchange of messages between user and system. Our theoretical assumptions will therefore also be informed by prior work on message interactivity (Sundar, 2007).

Before considering potential effects of *different* interactive features on different parts of a news article, we first provide a short outline of how interactive infographics might elicit cognitive responses at all. Visual elements have a long history in news because they can lend an aesthetic touch to the outlet, capture readers' attention, and support their understanding of the news message (Holsanova et al., 2006; Newhagen & Reeves, 1992)—at least when they are directly related to the accompanying text (de Haan et al., 2018). But what happens when interaction techniques are added to the visual? Existing research points to competing theoretical mechanisms by which interactivity can affect knowledge acquisition. On the one hand, interactive interface features have been found to place considerable demands on news consumers' limited cognitive resources, which are no longer available for processing the relevant content (Lang, 2000; Sweller, Ayres, & Kalyuga, 2011). In particular, it is assumed that interactive tools induce users to focus more on the interaction task itself (i.e., on the visual changes on the interface) than on the underlying information (Oh, Kang, Sudarshan, & Lee, 2020; Wise & Reeves, 2007). Moreover, they require users to come up with their own strategy to explore and interpret the information. When navigating an interactive visualization that is considered complex or confusing, users may not be able or willing to thoroughly process all information available and may be distracted from enjoyable consumption and successful learning (Bucy, 2004; Greussing, 2020; Van Damme, All, De Marez, & Van Leuven, 2019).

On the other hand, it is argued that allowing users to control the presentation of information can enhance their concentration and motivation, which contributes to an efficient use of cognitive resources and to the creation of more systematic thoughts in response to website information (Evans & Gibbons, 2007). The perceived attractiveness of interactive content has been found to play an important role in this respect (Plass & Kaplan, 2016). Research on user engagement (O'Brien & Toms, 2008; Oh, Bellur, & Sundar, 2018) indicates that interactivity can result in a positive assessment of the interface (i.e., aesthetic appeal), followed by a cognitive engagement with the associated content. Cognitive engagement here comprises two distinct, but related, concepts (Oh & Sundar, 2015): absorption and elaboration. Absorption refers to a state of deep involvement with the media environment, in which users are cognitively and affectively invested and experience heightened levels of attention, curiosity, and enjoyment (Agarwal & Karahanna, 2000). Elaboration refers to the act of making mental connections among related pieces of information (Eveland & Dunwoody, 2001): The more thoroughly an individual thinks about new information, the more sustainable linkages between the new information and already existing knowledge structures are established, which manifests the concept of learning (Mayer, 2014). Although previous research on Human-Computer-Interaction (HCI) has provided a comprehensive explication of absorption and elaboration (Oh & Sundar, 2015), it has not established a clear link between them. Yet, because absorption involves a high level of attention and motivation (Agarwal & Karahanna, 2000), which in turn are important prerequisites for elaborative processing (Birnboim, 2003; Petty & Cacioppo, 1986), it might serve as a connecting piece, linking the aesthetic appeal of interactive infographics with cognitive responses (see also van Noort et al., 2012, for a similar approach). These theoretical and empirical insights lead into a conceptual framework, as presented in Figure 1.

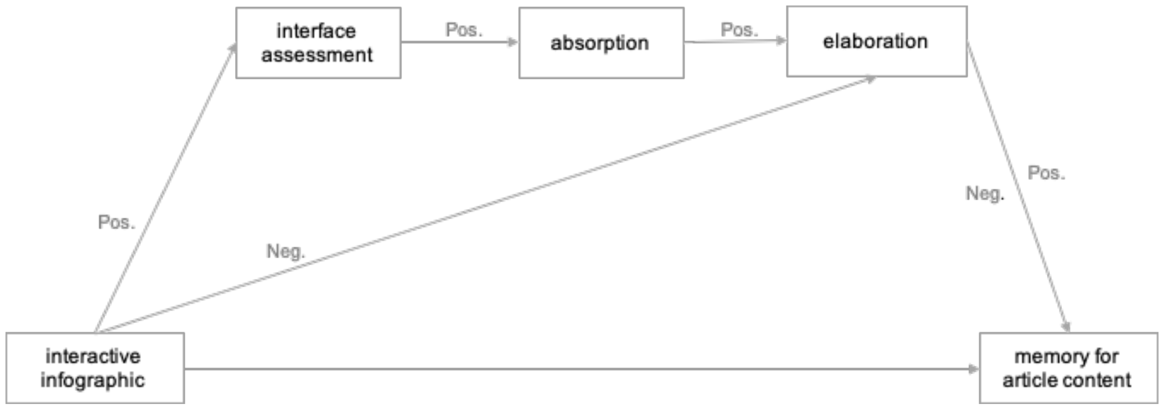

Figure 1. Conceptual framework. Pos. indicates a positive relationship, and Neg. indicates a negative relationship between the variables in the model.

Empirical evidence shows that interactive infographics elevate user ratings of website appeal compared with conditions in which content remains static (Bussemas, 2018). Apparently, the ability to interact with an image in a playful way not only catches users' attention, but also serves as a heuristic cue that invokes conscious acknowledgments of the novelty and aesthetic pleasure of the digital environment (Wang & Sundar, 2018). We therefore expect positive effects of interactive infographics on interface assessment and propose the following mediation hypothesis, guided by the aforementioned conceptual model:

H1: Adding an interactive infographic to a text-based news article will enhance memory of the entire article content serially through more positive interface assessment, higher levels of absorption, and higher levels of elaboration.

Although modality interactivity has been found to attract and absorb users, it might not always be beneficial for elaboration and memory, particularly when applied to news websites (Yang & Shen, 2019). Studies focusing on interactive infographics corroborate this result, reporting no support for greater recall or understanding of information presented in data visualizations that offer greater interactivity (Bussemas, 2018; Lee & Kim, 2016; Wojdynski, 2015). Consequently, for indirect effects solely established by elaboration, we propose a competing hypothesis:

H2: Adding an interactive infographic to a text-based news article will diminish memory for the entire article content through lower levels of elaboration.

Differentiating the Independent Variable: Clicking and Sliding

Different affordances provide different possibilities to access and experience content (Weber, 2017). The interactive potential of different interface features, however, does not necessarily correspond to the degree to which users *perceive* that they have control over the communication process (Bucy & Tao, 2007). In particular, low-level affordances, such as clicking on hyperlinks, may no longer be perceived as interactive (Voorveld, Neijens, & Smit, 2011; Yun, 2007). This is notable because visualizations that offer simple forms of interactivity, such as internal links, are most common (Young, Hermida, & Fulda, 2018; for online newspapers, see Zwinger & Zeiller, 2016). According to Sundar and colleagues (2014), the way individuals perceive and encode information when using interaction techniques further depends on their naturalness and intuitiveness (i.e., how closely a technique replicates interaction with real-world objects). In this sense, a slider bar is conceptualized as a navigation-based tool that tends to simulate motion. In Sundar and colleagues' (2014) experimental study, the most positive effects on both recall and pictorial recognition were indeed obtained for horizontal movements of a slider bar, whereas more complex tools, such as 3D carousels, were found to diminish knowledge uptake (Sundar et al., 2014). Clickable hotspots represent information-based tools that bring up more information when requested by the user (Sundar et al., 2014). In addition, they might provide a sense of back-and-forth interaction, and thus a sense of contingent message exchange with the system ("message interactivity"; Sundar, 2007, p. 94). Even though the navigation history is not displayed in the infographic, successively accessing pieces of content might enhance users' attention to the news message rather than to the visual changes on the interface and thus support elaboration (Oh & Sundar, 2015). Against this backdrop and acknowledging the external validity of the experimental approach (Zwinger & Zeiller, 2016), the present study differentiates among the effects of infographics with clickable hotspots and infographics with a slider bar, and poses the following research question:

RQ1: *Does clicking on an infographic vary in its effects on memory for the entire article content from sliding on an infographic?*

Differentiating the Dependent Variable: Potential Effects on the Surrounding Text

Considering that news articles commonly consist of a mixture of interactive and noninteractive (i.e., text-based) parts, the question arises whether news consumers' cognitive responses to modality interactivity might differ between these parts. Again, the answer is multidirectional, depending on what theoretical mechanism underlying the effects of interactivity is assumed. From the perspective of limited capacity models (Lang, 2000; Sweller et al., 2011), one would expect an interactive infographic to have a negative impact on the encoding, processing, and storing of the surrounding written information. In this case, users would take up information neither from the interactive infographic nor from the surrounding text. Xu and Sundar (2016) indeed show that the allocation of cognitive resources to, and the processing of, text-based content change when it is surrounded by an interactive product picture, such that highly interactive content occupied the major part of the time users spent on the website, reducing their attention for the noninteractive part and thus their ability to remember its content. From the perspective of user engagement research, by contrast, interactive infographics can absorb users into the news story (O'Brien & Toms, 2008; Oh & Sundar, 2015), arousing their interest and desire to learn more. As a consequence, users' attention to and processing of the surrounding text would be enhanced, which results in better memory for both the interactive infographic and the surrounding text. Studies indicating that news consumers use infographics primarily to support comprehension of the central article text (de Haan et al., 2018) even point to an additional pattern of effects: If the interactive features are not engaging enough—which might be possible in terms of the rather common clickable hotspots (Yun, 2007)—users may simply abandon the interactive part of the news article and allocate their full attention to the written material. In this case, interactive features would help users to acquire information presented in the surrounding text, but hinder them from acquiring information presented in the interactive infographic. Given the inconclusive evidence base, we propose the following research question:

RQ2: Does the addition of either a clickable or a slider-based infographic to a text-based news article differentially affect memory of content presented in (a) the infographic and (b) the surrounding text?

Methods

To answer the research questions and hypotheses outlined earlier, an online survey experiment was conducted in 2018, structured as a between-subjects design with 293 participants randomized[1] into three groups. Participants in the two experimental groups were exposed to a news article that included an interactive infographic with either clickable hotspots or a slider bar. Participants in the control group were exposed to a news article with identical content, but no infographic (text only). Overall, a sample of 293 members of the general Austrian population aged 18–65 years participated in the experiment (47% female; mean age = 42.5, *SD* = 12.7). They were recruited from a national online panel pool maintained by the Austrian market research company MindTake in accordance with a stratified quota sampling method. Initially, 300 people participated in the study, but seven individuals were excluded from the analysis because they either went back in the survey to see the stimulus article more than once or reported major technical problems when accessing the stimulus website. After signing a consent form, all participants read a short introductory message informing them that the purpose of the study was to obtain their opinion about a news article on climate change. They further completed an initial set of questions assessing demographic data, online news use, and Web experience. Participants were then randomly assigned to one of the three groups and redirected to an external website to closely read the stimulus article. Afterward, they were asked to complete a second set of questions that assessed their affective and cognitive experiences during exposure to the stimulus as well as their knowledge. At the close of the survey, a debriefing message with information about the true nature of the study was presented to all participants.

Stimulus Material

To experimentally assess the effects of interactive infographics on knowledge, a stimulus is required that (1) discusses a topic of some level of complexity that lends itself for presentation in such graphics, but that can also be presented in plain text form without losing substantial information, and (2) addresses a topic that potentially resonates with recipients' prior knowledge while presenting information sufficiently novel to allow for learning effects. Therefore, the stimulus material consists of a news article about the impact of a dramatic slowdown of the Atlantic currents on European climate, which was created based on coverage by German-speaking quality newspapers. The topic combines a niche aspect of the climate change debate with general information on ocean currents. Hence, although the topic was not salient in the news at the time the experiment was conducted, it is assumed that participants may have some prior knowledge

[1] A randomization check on age, gender, education level, and online news use revealed that the randomization was successful, with no between-group differences for the sample ($p > .05$).

about it, with which the information presented in the stimulus could be integrated (Oschatz, 2018). Moreover, its newsworthiness is plausible because the topic is still under scientific debate (Hutsteiner, 2018).

To secure informational equivalency, all three conditions provide the exact same content. Two groups were exposed to a news article accompanied by one interactive infographic, while the control group was exposed to a text-only condition, where all written information included in the infographic was presented as one paragraph of text ("text-only condition," N = 99). Identical material was used to carefully create the two different versions of the infographic. The first interactive infographic ("clickable condition," N = 99) consisted of a still image that schematically illustrates the flow path of the Gulf Stream system between North America and Europe, with arrows indicating the flowing direction and written inserts—consecutively numbered from 1 to 4—explaining the content. Readers were able to show and hide these inserts by clicking on small icons placed next to them. The still image used in the clickable condition was a screenshot of the final frame of a 45-second computer-based animation, which was used in the second interactive version of the stimulus ("slider condition," N = 95). The animation was divided into 50 single frames, and participants needed to move a slider to manually advance it frame by frame. Thus, they had control over the pace and were able to go back and forth easily. Written subtitles presenting the same text as the inserts in the clickable condition were used to explain the content. The animation was originally produced by the German public-service broadcaster ARD (2014) and adapted to fit our experimental design (see "Was bringt der Klimawandel für Europa?" for the original material; screenshots and links to video clips of the interactive infographics can be found in Appendix). The average time participants spent with the stimulus article (i.e., exposure time) across all conditions was 2.6 minutes.

In general, the structure and layout of the news article were kept entirely the same; visuals were matched for size and placement in the story. A pretest, conducted via the crowdsourcing platform Crowdflower (N = 101 Austrian-based contributors), ensured that the news article and the two infographics used in the experiment were perceived as professionally designed (M = 3.6, SD = 1.6, all measured based on a 5-point scale from 1 to 5, where 1 means *unprofessional*); were comprehensible for a nonexpert audience (M = 3.3, SD = 1.6); and did not cause any technical or usability problems.[2] No significant differences between the conditions were obtained (p > .05). Participants in the main study were also asked to rate the usability and professionalism of the stimulus, indicating no significant differences between the experimental conditions (p > .05).

[2] Apart from their general user experience, participants in the pretest were asked about specific obstacles that may be associated with a particular presentation form. Eighty-three percent of the participants exposed to the clickable condition realized that the inserts were placed in a particular order, and 58% immediately followed this order when attending to them. Sixty-nine percent of the participants exposed to the slider condition attended to the written inserts (another 26% reported "partly"), and 61% immediately recognized when new information was displayed (another 35% reported "partly"). For the interactive conditions, we further asked whether users had any problems understanding how the interactive features worked. No problems were reported for either the clickable hotspots or the slider bar.

Measurements

Dependent Measure: Memory for Article Content

As suggested by Eveland and Dunwoody (2001), memory for article content was measured using two types of variables: recognition and cued recall. Recognition was captured by five multiple-choice questions, with one question pertaining to information covered in the infographic (see the online supplementary file[3] for the original wording of all items). To avoid guesswork, participants were offered the option of clicking "I don't know." Correct answers were recoded as 1, and all other answers (including "I don't know") were recoded as 0. Cued recall was captured by four open-ended questions, with answers ranging from stating a number to explaining a causal mechanism. One question pertained to information covered in the infographic. Participants were invited to note "I don't know" if they could not remember the correct answer. While questions concerning recognition were dummy coded (i.e., correct = 1 vs. incorrect = 0), for open-ended cued recall questions, participants earned partial points for each piece of information correctly mentioned. A complete open-ended answer represented 1 point. For subsequent data analysis, the coding of the recall and recognition measures was combined to form a sum index of news acquisition (M = 4.0, SD = 2.4, theoretical range = 0 to 9). Cued recall and recognition were assessed after measuring the mediator variables to minimize the risk of participants adjusting their self-reported cognitive engagement based on their ability to remember information.

Mediators: Affective and Cognitive Responses to the Stimulus

Because affective and cognitive responses were conceptualized as mediators in our model, they were asked for directly after the participants had read the stimulus article. Measures were adopted from indicators used in past research on user engagement with online messages, modified to fit the context of the present study. All items were measured on a 5-point scale (1 = *strongly disagree*, 5 = *strongly agree*) and subsequently averaged to produce single variables. Interface assessment was measured by a semantic differential with five items, referring to the perceived attractiveness, originality, and complexity of the layout (M = 3.1, SD = 0.7, Cronbach's α = .84). Following Agarwal and Karahanna (2000), a six-item scale captured participants' level of absorption, that is, their experience of focused attention, curiosity, and heightened enjoyment, as well as their feeling of losing track of time and of the outside world while reading the stimulus article (M = 3.3, SD = 0.9, Cronbach's α = .86). Elaboration was based on Mayer's (2014) conceptualization of meaningful learning, which suggests that meaningful learning occurs when individuals select relevant information from the material presented, organize it into a coherent mental model, and link it to existing knowledge structures. It was measured using six indicators (M = 3.6, SD = 0.8, Cronbach's α = .80) adopted from Appel, Koch, Schreier, and Groeben's (2002) measurement of ease of cognitive access; Oh and Sundar's (2016) measurement of imagery engagement; and Kahlor, Dunwoody, Griffin, Neuwirth, and Giese's (2003) message elaboration scale.

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[3] The document can be accessed here:
https://www.dropbox.com/s/ylaafjh9cbauy2t/Online_supplementary_file_IJoC_article-ID15419.pdf?dl=0

Covariates

To control for individual differences that may influence the relationships tested in our analyses, participants were asked to report their age, gender, formal education level, and overall Web experience. Web experience, which has been found to be an important predictor in HCI research (Sundar & Marathe, 2010), was measured via self-assessment. Using a scale from 1 to 5, respondents indicated their overall level of experience using the Internet (1 = *not experienced at all*, 5 = *very experienced*; M = 3.7, SD = 0.9). In addition, we controlled for the duration of reading the stimulus article in minutes (i.e., exposure time). We also included perceived interactivity to account for a possible confound of interactivity. Based on the operationalization of modality interactivity (Sundar, 2007), in this study, participants were able to control the content presented in the interactive infographics by either clicking on hotspots or moving a slider bar. Hence, perceived interactivity was measured by asking participants to indicate their agreement with the statement, "I felt like I had control over the presentation of content" (1 = *strongly disagree*, 5 = *strongly agree*; M = 3.6, SD = 1.1).

Analytic Approach

In a first step, to examine the direct and indirect effects of being exposed to either a clickable infographic or a slider-based infographic on learning from news (RQ1), and to test the hypothesized mediation paths through interface assessment, absorption, and elaboration (H1, H2), we performed PROCESS modeling with 10,000 bootstrap resamples and 95% percentile confidence intervals. Using Hayes's (2017) PROCESS macro (version 3.0, Model 6), we relied on a serial mediation analysis with a multicategorical independent variable with three dummy-coded categories. This allowed us to simultaneously examine the direct and indirect effects of each variable of interest on the outcome variable while formally testing the significance of specific indirect effects in the mediation path based on OLS regressions (Preacher & Hayes, 2008). The text-only condition thereby served as reference group, relative to which the two experimental conditions were tested. Web experience and exposure time were included as controls. In a second step, we applied an analysis of covariance (ANCOVA) model with Web experience and exposure time as covariates to differentiate the direct effects of clickable hotspots and a slider bar on acquisition of information presented in the infographic, and acquisition of information presented in the surrounding text (RQ2).

Results

To better understand the mechanisms that drive the effects of interactivity in infographics, we start by looking at the relative direct and indirect effects establishing the relationship between the clickable and slider-based graphics, respectively, and information acquisition (H1, H2, RQ1; see Table 1).

Table 1. Results of the Serial Mediation Analysis: Relative Direct and Indirect Effects.

		Text-only condition	
		vs. clickable condition	vs. slider condition
Partially standardized relative direct effect (RQ1)		−.45 [−.68, −.19]	−.30 [−.55, −.05]
Partially standardized relative indirect effect [95% CI]	Through interface assessment → absorption → elaboration (H1)	.08 [.04, .13]	.08 [.04, .14]
	Through elaboration (H2)	.01 [−.07, .10]	.02 [−.07, .10]
	Through interface assessment	−.12 [−.23, −.02]	−.12 [−.23, −.02]
	Through absorption → elaboration	−.04 [−.11, .02]	−.06 [−.13, −.004]

Note. Regression-based serial mediation analysis with 10,000 bootstrap resamples and 95% percentile confidence intervals (*N* = 293). Dependent variable: memory for entire article content. Control variables: Web experience, exposure time. Because of the multicategorical predictor variable, regression coefficients are in partially standardized form.

The path model based on the partially standardized regression coefficients obtained from the serial mediation analysis, including interface assessment, absorption, and elaboration, is illustrated in Figure 2. The R^2 for the overall model is .19, indicative of a small to medium goodness-of-fit, according to Cohen (1992).

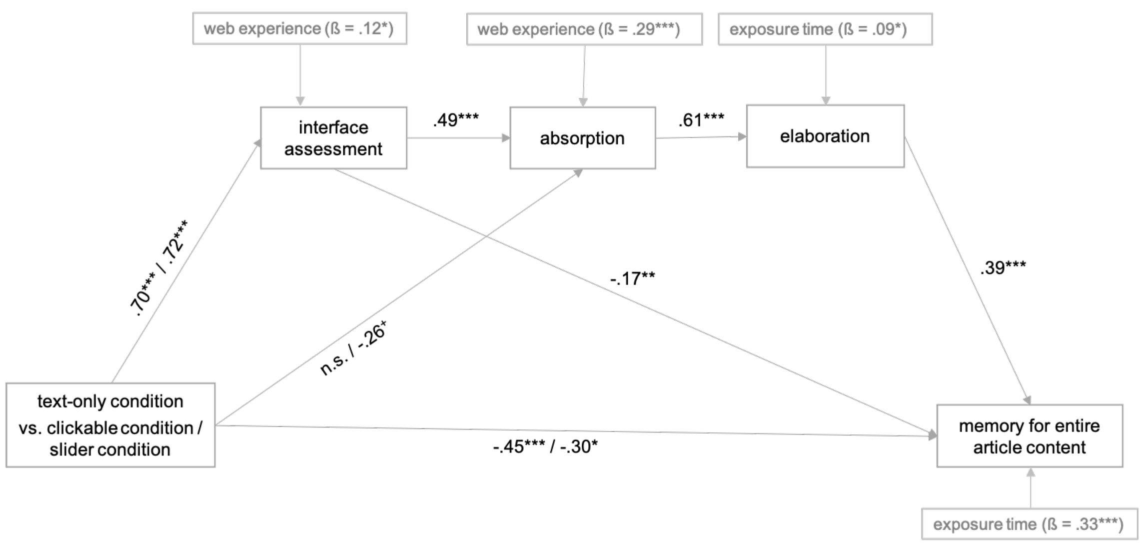

Figure 2. Path diagram of the serial mediation. Values are partially standardized regression coefficients (N = 293). Exposure time and Web experience serve as controls. *** p < .001. ** p < .01. * p < .05. + p < .06; n.s. = nonsignificant.

Overall, the model shows significant negative relative *direct* effects of the clickable and the slider-based infographic on learning (partially standardized point estimate for the clickable condition: −.45, *SE* = .29, $p < .001$; for the slider condition: −.30, *SE* = 0.30, $p < .05$). That is, participants who were exposed to an infographic with clickable hotspots or an infographic with a slider bar learned less than those who were exposed to the same content in plain text. A closer inspection of the relative *indirect* effects, however, paints a more nuanced picture. As predicted by H1, both the clickable graphic and the slider-based graphic led to a significantly better assessment of the interface than the plain text ($ß_{clicking}$ = .70, $p < .001$; $ß_{sliding}$ = .72, $p < .001$). Moreover, as further predicted by H1, the serial mediation analysis reveals a positive indirect effect representing the underlying psychological mechanism through which the influence of infographics on information acquisition is established: Adding a clickable or slider-based infographic to a news story improves the evaluation of the website's layout, which leads to enhanced absorption in the content; this in turn is positively related to elaboration, which, finally, leads to better learning outcomes. The partially standardized indirect effect for both clicking and sliding is .08 (*SE* = .02, 95% CI [.04, .13] and *SE* = .03, 95% CI [.04, .14], respectively).

The negative indirect path predicted by H2, however, was not confirmed by our data. Instead, a negative pattern was found for evaluation of the interface and acquisition of information, suggesting a negative indirect relationship between adding an interactive infographic to a text-based news article, and information acquisition through interface assessment. This path does not include variables of cognitive processing; it only considers the perception of the interface. It represents the largest indirect effect found in this study: For both, clicking and sliding the partially standardized indirect effect was −.12 (*SE* = .05, 95% CI [−.23, −.02]). Moreover, a second unexpected negative relative indirect effect was found, linking the slider condition to knowledge acquisition through absorption and elaboration, with a partially standardized indirect effect of −.06 (*SE* = .03, 95% CI [−.13, −.004]). Interestingly, here no mediator representing how users perceived the infographic (i.e., interface assessment) was included, but the presence of modality interactivity directly hindered users from becoming absorbed in the content. This indirect effect did not appear for the clickable condition. The model further points to the relevance of exposure time and Web experience, which were included as a control. It appears that exposure time affects elaboration (ß = .09, $p < .05$) and knowledge acquisition (ß = .33, $p < .001$). Web experience, by contrast, affects interface assessment (ß = .12, $p < .05$) and absorption (ß = .29, $p < .001$).

In line with our second research question, we continued exploring the direct effects of interactive infographics on learning from news by differentiating the dependent variable. A one-way ANCOVA with Bonferroni correction testing for content presented in the infographic while controlling for exposure time and Web experience (RQ2a) revealed that both the clickable and slider-based condition led to significantly lower memory than the text-only condition: $F(2, 288) = 11.1$, $p < 001$, partial $\eta^2 = .07$. The mean difference was 0.4 for both the clickable and slider condition. For memory of content presented in the surrounding text (RQ2b), the data revealed a similar pattern of effects: $F(2, 288) = 4.3$, $p < .05$, partial $\eta^2 = .03$. However, here the effect stemmed solely from comparing the text-only condition with the clickable condition (mean difference = 0.8, *SE* = 0.3); a comparison with the slider-based condition turned out to be nonsignificant. In all models, there was no significant difference between the two interactive infographics ($p > .05$; see also Table 2).

Table 2. Results of ANCOVA Models for Memory for Article Content.

Memory for content of . . .	Condition	*M*	*SE*
The infographic (RQ2a)	Text-only	0.9_{A}	.06
	Clickable	0.5_{B}	.06
	Slider	0.5_{B}	.06
The surrounding text (RQ2b)	Text-only	3.7_{A}	.19
	Clickable	3.0_{B}	.19
	Slider	$3.3_{A, B}$	.20

Note. Values given are means and standard errors for each condition. Means with different subscripts differed significantly from each other using the Bonferroni post hoc test ($p < .05$). Exposure time and Web experience served as covariance.

To make sense of these results, we explored whether clicking and sliding would lead users to experience the same degree of interactivity. Our data suggest that clicking and sliding did not uniformly affect users' perception of being in control over the information flow; only the slider-based graph significantly enhanced users' level of perceived interactivity compared with the text-only condition, with a mean difference of 0.35 ($p < .05$). For the clickable graph, no significant effect on perceived interactivity was found, indicating that the users did not experience the interactive potential inherent in clicking on hotspots.

Discussion

The present study was designed to investigate an important, but understudied, question in the reception of contemporary online media: How do interactive infographics affect individuals' understanding of news? To extend previous research in this area and make more nuanced statements about how interactive infographics affect the learning process, we isolated the influence of a slider graph and a clickable graph to see whether different interactive features might shape this relationship differently. Moreover, we differentiated between memory for the entire news article, memory for information presented in the infographic, and memory for content presented in the surrounding text. Finally, we tested a model with interface assessment, absorption, and elaboration to better understand the underlying mechanisms of interactivity effects.

Most notably, and contrary to popular belief (George-Palilonis, 2017), our results suggest that interactive infographics can significantly impair news consumers' ability to understand and remember the content of a news story. Although there is a positive indirect effect triggered by the graphics' appealing layout, the negative direct effect is of such magnitude that the indirect effect cannot compensate for it. In terms of limited capacity models (Lang, 2000; Sweller et al., 2011), both types of infographics appear to present information in a way that exceeds users' cognitive resources by requiring them to split their attention between the different elements of the news article and to mentally coordinate the information they provide. However, memory for graphical content and memory for text-based content are compared, an interesting pattern emerges: While both clicking and sliding diminished recognition and cued recall of information presented in the infographic, participants in the slider condition apparently had enough cognitive resources left to attend to and process the information presented in the surrounding text; their knowledge uptake at least equals that generated by plain text. This pattern corroborates results from an earlier study by Sundar and associates (2014; see also Oh & Sundar, 2016), which found that users who accessed content by moving forward and backward on a timeline showed the best cognitive performance. It might be that when using a slider bar, users do not need additional cognitive effort to animate the movement in their mind (as they do when using a static image), and this frees up working memory resources (Hegarty, 1992). Nevertheless, given that readers had difficulty remembering the information presented in the infographic, it is also possible that they decided not to engage with the slider bar, but to allocate their attention mainly to the surrounding text (de Haan et al., 2018). Our data show that indeed, 29.5% of the participants exposed to the slider condition could not remember the general topic of the stimulus graphic (for participants exposed to the clickable condition, it was 15%; see Bussemas, 2018, and Drucker, Huron, Kosasra, Schwabish, & Diakopoulos, 2018, for similar notions). These numbers primarily speak to media practitioners, because interactive visual designs are adopted in the hope of arousing interest (George-Palilonis, 2017).

Infographics that invite users to click on hotspots might lead to information acquisition via different mechanisms than infographics that invite users to move a slider bar. Our results indicate that clicking on consecutive hotspots was unlikely to be perceived as an interdependent exchange with the system, given that it did not support message elaboration (Oh & Sundar, 2015). Further studies that empirically measure users' perceived contingency would nevertheless be important here. In addition, unlike sliding, clicking on hotspots might be so common in digital environments that participants did not perceive it as more interactive than plain text, which only requires users to scroll down the page. The theorization of the effects of interactivity in online news needs to reflect this finding. It seems as if interactive infographics do not influence the acquisition of knowledge through their behavioral characteristics—that is, the opportunity for users to behaviorally engage with information—but trigger an aesthetic appeal through their design: They serve as heuristic cues. Overall, our study profited from taking up a differentiated conceptualization of both the dependent and the independent variable. Future work is needed to systematically investigate the relationship between different interactive features and different types of visual content when embedded in a written text. Experimental designs that apply eye-tracking methodology or draw on the server logs are a promising avenue in this respect. Server logs would also allow researchers to distinguish between different levels of interactivity, and thus to further investigate the notion that the effect of low, medium, or high levels of interactivity on elaboration is not linear, but curvilinear (Oh & Sundar, 2015).

In reference to current research on user engagement with interactive media (O'Brien & Toms, 2008; Oh & Sundar, 2015; van Noort et al., 2012), the serial mediation model tested in this study highlights an important perspective on learning from news by showing that interactive infographics can alter the understanding of a news article without directly affecting cognitive processing. Our results indicate that interactive infographics drive the perceived attractiveness of the interface and that an attractive interface increases cognitive absorption, which in turn leads to more efficient elaboration and better learning outcomes. However, simply liking the interface is apparently not sufficient. The unexpected negative mediation path running from the stimulus article to information acquisition only via interface assessment reminds us that engaging with an interactive infographic requires additional cognitive resources for decisions about which control panel should be executed and how. Hence, interactive visual elements run the risk of ruining their initial advantages by interrupting deeper reasoning and taking away cognitive capacities that are needed to process and store the news content (Oh et al., 2020). This inference is supported by the second negative path, which runs through absorption and elaboration (and not directly through elaboration, as we would have predicted). The divergent effects yielded by the interactive infographics are an important issue for future studies: At what point in the reception process does the interactivity of information graphics overwhelm users and promote detrimental effects? Moreover, it seems that both affective and cognitive reactions to interactive infographics are important aspects of knowledge construction and the process of consuming news in digital environments. In addition, our study points to a considerable influence of Web experience and exposure time, included as controls in our model. It appears that users' overall level of experience using the Internet positively influences their affective engagement (i.e., interface assessment and absorption), while the time spent with the stimulus positively affects their cognitive engagement (i.e., elaboration and memory) with the news article. It thus might be fruitful to include exposure time and Web experience as moderators in the future (Sundar & Marathe, 2010).

A potential limitation of our study lies in the fact that the experiment was embedded in an online survey. Although this adds to external validity, because reception of the article arguably occurred in situations in which people would be more likely to attend to online news, the approach offers little control over to what degree and how participants actually interacted with the infographic during the exposure. Knowledge acquisition was also measured directly after reception, prohibiting any statements about the effects' stability over time. Moreover, just as many other studies in this area have done (e.g., Lee & Kim, 2016; Xu & Sundar, 2016), we employed a measure of knowledge that was strongly focused on factual information, requiring individuals to recognize and recall pieces of content presented in the stimulus article. Follow-up studies should therefore be conducted using a larger variety of knowledge measures, including open transfer items and items that assess structural knowledge.

Although we relied on a one-message design in our experiment, we believe that our results are likely to travel beyond our single message. We carefully crafted variation in the type of infographics while keeping substantial content highly comparable across manipulations. It is reasonable, therefore, to assume that effects are indeed driven by different ways of exploring the content rather than by specifics of the actual topic. Furthermore, we chose a topic that likely resonates somewhat with users' prior knowledge. However, future studies ideally should address interactive infographic effects with higher message variance (Thorson, Wicks, & Leshner, 2012), where, in particular, the complexity of the topic and its familiarity would be varied. Moreover, our study is limited to two (simple) types of infographics, and the findings are only applicable to news read on a desktop computer or tablet. On smartphones, interactive content might be evaluated and used differently because the small screen size changes the news experience; this raises further questions about the specific device used for reception as additional determinant of affective and cognitive reactions to interactive news. Overall, it is important to note that technical settings of the browser or device can considerably alter the experience of engaging with interactive infographics, or even make it impossible.

Despite these limitations, we demonstrate that allowing users to interact with information displayed in graphics cannot be expected to uniformly promote enhanced learning processes; instead, the impact of interactive news content depends on how specific interactive modalities initiate both affective and cognitive processes in audiences when they read online news. Hence, our study offers an important contribution toward a comprehensive understanding of learning from news with interactive visual elements and provides empirical evidence for the promises and pitfalls of interactive infographics that go along with their use in online news, but have seldom been systematically tested.

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Appendix: Stimulus Material

11

Klimawandel bringt Gefahr für den Golfstrom – und Europa mehr Kälte?

Warme Meeresströmungen bescheren uns in Europa gemäßigte Temperaturen. Neue Berechnungen zeigen, dass diese Strömungen durch den Klimawandel an Kraft verlieren und sogar zum Stillstand kommen könnten. In der Folge würden die Durchschnittstemperaturen in Zukunft deutlich sinken und trotz Treibhauseffekt lange Kaltphasen hervorrufen.

Meeresströmungen wirken sich weltweit auf das Klima aus

Ein beständig wehender Wind treibt warmes Oberflächenwasser vom Äquator in den Golf von Mexiko. Der Golfstrom wärmt sich dabei auf bis zu 30°C auf, bevor er durch die Erddrehung und die Westwinde abgelenkt wird und Kurs auf Europa nimmt. Vor Nordeuropa gibt er als nordatlantischer Strom viel Wärme ab. Dadurch steigt der Salzgehalt des Wassers – es wird schwerer und sinkt ab. Das kalte Wasser zirkuliert nun zurück Richtung Äquator, wo es sich erwärmt und die Reise erneut beginnt.

Information displayed in the interactive infographic

Wissenschaftler beschäftigten sich seit Jahren mit der Frage, ob der Golfstrom über die Zeit tatsächlich schwächer wird. Neue Modelle vom Potsdam-Institut für Klimafolgenforschung sprechen dafür. Wenn die Kohlendioxidkonzentration in der Atmosphäre weiter ansteigt, könnte sich im Nordatlantik die Luft so stark aufheizen, dass das Wasser des Golfstroms nicht mehr genug abkühlen kann. Es würde nicht wie gewohnt nach unten sinken und daher auch nicht zurück zum Äquator gelangen. Hinzu kommt das Abschmelzen des Grönlandeises, das amerikanischen Forschern zufolge den Effekt weiter verstärken könnte: Durch den geringen Salzgehalt des Schmelzwassers würde die Meeresströmung an Dichte verlieren und an der Oberfläche bleiben, was sie zum Erliegen bringen könnte.

Wie wahrscheinlich ist ein solches Szenario?

Eine Vielzahl an Studien zeigt, dass der Klimawandel einen Einfluss auf den Golfstrom hat. Was das konkret bedeutet ist aber unklar. Es gibt noch keine langfristigen Messreihen, um konkrete Vorhersagen zu treffen.
Experten gehen davon aus, dass die globale Erderwärmung den Effekt einer dramatischen Abkühlung Europas ausgleichen würde. Forscher in den USA nehmen sogar an, dass nicht die Meeresströmungen, sondern die Tropenwinde Wärme nach Europa bringen. Ein Versiegen der warmen Strömung hätte somit gar keinen Effekt auf unsere Temperaturen.

Im Extremfall könnte der Golfstrom innerhalb der nächsten 100 Jahre 30 Prozent seiner Kraft verlieren und in 300 Jahren komplett zusammenbrechen. Trotz Gefahr einer Abkühlung wird es bis zur nächsten Eiszeit aber noch mindestens 30.000 Jahre dauern.

Belege für die Entwicklung der Meeresströme gewinnen Wissenschaftler durch Temperaturmessungen an der Wasseroberfläche. Die Temperaturen vergangener Jahrhunderte ermitteln sie aus der Analyse von Korallen, Baumringen oder Eisbohrkernen.

Trotz vieler Unklarheiten und weiterem Forschungsbedarf nimmt die Wissenschaft das Thema sehr ernst, denn die Ozeanzirkulation ist eine empfindliche Stelle im Klimasystem. „Schon eine kleine Veränderung der Strömung kann die Ökosysteme des Ozeans stören, und damit auch die Fischerei und die Lebensgrundlage vieler Menschen an den Küsten", schätzt das Potsdam-Institut für Klimafolgenforschung. Die Klimaveränderung ist dann nicht mehr nur ein ökologisches, sondern auch ein wirtschaftliches Problem.

Figure A1. Screenshot of the stimulus article (text-only condition).

Figure A2a. Screenshot of the clickable condition interactive infographic. Video clip that shows how the interactive elements work can be found when clicking on the link. stimulus material (2020a).

Figure A2b. Screenshot of the slider condition interactive infographic. Video clip that shows how the interactive elements work can be found when clicking on the link. stimulus material (2020b).