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Processing Explicit and Implicit Causal Relations in L2 Reading

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1. Introduction

The goal of this study was to examine whether and how second-language (L2) readers understand causal relations in expository text during reading (i.e., *on-line*). Expository text communicates new information to readers. Successful expository comprehension in L2 allows students to learn not only linguistic elements (e.g., words, grammar) in the text but also information conveyed by the author (Kintsch, 1994). It is widely acknowledged that such *learning from text* can be achieved by understanding causal relations in text, whereby readers construct coherent mental representations of situations of the text, known as *situation models* (Kintsch, 1998).

However, it is often difficult for L2 students to successfully understand how text sentences are related to one another. This is largely because relations between sentences in text are not usually explicit. Rather, they often remain implicit. When relations between pieces of information are implicit, their understanding requires readers to make inferences, which is cognitively demanding for less-skilled readers, such as L2 readers as well as first-language (L1) young children. In order to provide a theoretical basis to support the difficulty associated with L2 readers' learning from text, this study was designed to explore L2 readers' comprehension processes of causal relations in the expository text. Specially, this study focused on the explicitness of causal relations and investigated whether and how L2 readers implement different comprehension processes as a function of the explicitness of causal relations.

1.1 Processing Causal Relations During Text Comprehension: The Causal Network Model

Causal relations constitute an essential basis on which text eves are logically and coherently connected. Construction of situation models largely depends on readers' ability to detect and understand causal relations in text (McCrudden, Schraw, & Lehman, 2009; Millis, Magliano, & Todaro, 2006; Mulder, 2008). Theoretically, causal relations in discourse are defined with reference to the *causal network model* (Langston & Trabasso, 1999; Suh & Trabasso, 1993; Trabasso & Sperry, 1985; Trabasso & van den Broek, 1985; Trabasso, van den Broek, & Suh, 1989). The causal network model identifies causal relations in text based on the *logical criteria of necessity*. Event A is necessary for Event B if Event B does not occur in the described text situation without Event A. This procedure is called the *causal network analysis*. Consider Magliano and Millis's (2003, p. 256) sentences, for example. Figure 1 illustrates the causal relations between these statements, with each relation expressed with the arrow. The causal network analysis judges Sentences 2, 3, and 4 to be directly related to Sentence 5. In other words, the events in all three statements are necessary for the event in Sentence 5 to occur; had the rich lord not liked to collect carvings of animals, had a mouse carving, or not called the skilled carvers, then he would not have asked the carvers to make a carving of a mouse.

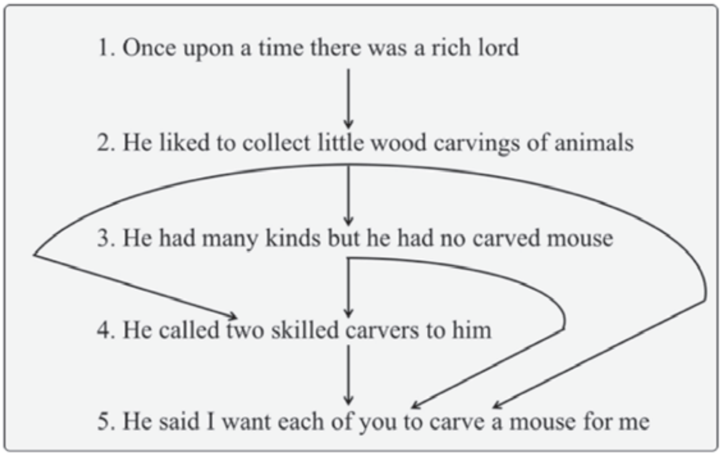

Figure 1. A causal structure of the five sentences adapted from Magliano and Millis (2003, p. 256).

As this example shows, performing the causal network analysis yields a network of statements linked by causal relations where some statements have more causal connections (CCs) than others. Information from this *causal structure* can be used to assess on-line reading processes as well as after-reading (i.e., *off-line*) text memory (e.g., Suh & Trabasso, 1993; Trabasso & Suh, 1993; Trabasso et al., 1989). For example, the model predicts that if readers understand text by means of causal relations, they take less time to read statements with many CCs to the previous part of the text than statements with fewer CCs. This prediction has widely been supported by past studies using narrative text. Considerable studies on L1 narrative reading reported shorter reading times as a function of the number of CCs (e.g., Magliano, Trabasso, & Graesser, 1999; Radvansky, Tamplin, Armendarez, & Thompson, 2014). This indicates that L1 readers sensitively understand causal relations in narrative text. In addition to L1, some L2 studies showed shorter reading times for narrative statements with increased CCs (Ushiro et al., 2010), providing the evidence that L2 readers also understand narrative text's causal relations during reading.

Although these findings are important in showing the understandability of narrative text's causal relations, several points must be noted. First, compared to narrative text, quite limited studies have applied the causal network model to expository text that is the focus of this study. Second, whether, and if so, how readers process causal relations of different explicitness is unresolved. The following two sections discuss these points, respectively.

1.2 Causal Relations in Expository Text

Exceptional studies applying the causal network model to expository comprehension processes are those of Millis, Magliano and his colleagues (Mills et al., 2006; Magliano, the RSAT Development Team, Levinstein, & Boonthum, 2011). They reported that skilled L1 readers routinely bridge the current statement and the prior text by means of causal relations when that statement shares causal relations to the prior text. Regarding L2 reading, only Ushiro et al. (2015) used the causal network model with expository text. They showed that Japanese university students' off-line text memory was sensitive to causal relations in expository text such that statements with more CCs to the rest of the text were recalled better than statements with fewer CCs. Note, however, that Ushiro et al. only used off-line measures that assessed text memory resulted after reading. Evidence is scarce about on-line processes associated with L2 readers' moment-by-moment understanding of causal relations in expository text.

It is also important to note that causal relations in expository text are more difficult to understand than causal relations in narrative text. The primary reason is that content of expository text is less familiar than that of narrative text (Britten & Gülgöz, 1991). Specifically, causal relations in narrative text consist of characters' goal-action relations that are embedded in typical readers' daily lives. By contrast, causal relations in expository text consist of physical or scientific events, such as mechanisms about how scientific phenomena occur and how physical components in specific systems work (Graesser & Hemphill, 1991). Because this kind of information is abstract and technical, lower-level reading processes (e.g., word recognition, syntactic parsing) involved in comprehension of expository text require higher cognitive demands than those in narrative comprehension (Horiba, 2000; Shimizu, 2015). Consequently, readers of expository text have increased difficulty with integrative processes.

1.3 Understanding Implicit Information During Reading

The present study tried to advance past causal network model studies by extending this model to implicit causal relations. Researchers agree that understanding implicit information requires readers' inference generation (e.g., Hosoda, 2014; Kintsch, 1998; Singer, Harkness, & Stewart, 1997). To illustrate, consider the second sentence pair in Table 1 (adopted from Myers, Shinjo, & Duffy, 1987). To causally understand this pair, readers have to infer an implicit idea (e.g., Joey's mother punched him) that explains how the events in the sentences can be connected. Such inference generation is known to manifest itself as delayed processing times as relative to when the inference is not made (Hosoda, 2014; Singer et al., 1997). Actually, Myers et al. found that the second sentence pair in Table 1 elicited longer reading times than the first sentence pair where the causal relation between the sentences is more direct with little room for inferences.

Table 1

Sentence Pairs With Causal Relations of Different Strengths

1.	Joey's brother punched him again and again. The next day his body was covered with bruises.
2.	Racing down the hill, Joey fell of his bike. The next day his body was covered with bruises.

Based on this view, the present study predicted that readers would take longer reading times as a function of the number of CCs when causal relations between statements are implicit.

At the same time, it is well known that L2 readers have difficulty generating inferences during expository reading (Hosoda, 2014). This implies the possibility that implicit causal relations would not be easily available for on-line L2 expository comprehension processes, and therefore, the relation between CCs and reading times would not be straightforward.

2. The Present Study

This study drew on the causal network model and aimed to reveal the extent to which L2 readers understand explicit and implicit causal relations in expository texts. This study predicted that when causal relations are made explicit in text (called the *explicit condition* hereafter), reading times for any given statement should be shorter as a function of the number of CCs. This is because causal relations should be relatively readily available to readers in this case, as those relations are directly signaled. On the other hand, when causal relations remain implicit (called the *implicit condition*), reading times are predicted to be longer as a function of the number of CCs. This prediction is because integrating current statements with the prior text in the implicit condition should involve readers' inferring causal relations, which delays reading times.

Given these predictions, I placed the focus of this study on the interaction between the number of CCs and the explicitness of causal relations in statement reading times. The following research question (RQ) was addressed in this study.

RQ: Do the number of CCs and the explicitness of causal relations interactively affect L2 readers' reading times for the expository text?

3. Method

3.1 Participants

Fifty-two Japanese undergraduate and graduate students took part in the experiment. Their majors were various, including literature, education, humanities, psychology, social studies, agriculture, engineering, and international studies. Twenty-nine of them were female, and the other 23 were male. Their ages ranged from 18 to 27 years (M = 20.29, SD = 1.50). All of them had studied English for more than six years. Their self-reports indicated that participants had overall English proficiency of the CEFR A2 to B2 levels (Council of Europe, 2001); the TOEIC listening and reading test (M = 638.99, SD = 111.09, range = 405 to 920) and the EIKEN test (Grade 4 to Grade 1: Grade 4, n = 2; Grade 3, n = 2; Grade Pre-2, n = 3; Grade 2, n = 12; Grade Pre-1, n = 6; Grade 1, n = 1). Forty-four participants reported at least one of the scores, and the other eight participants reported none of the scores. Participants were grouped into those who read the explicit text (n = 26) and those who read the implicit text (n = 26).

3.2 Material

Text and explicitness manipulation. I employed the expository passage used in past expository comprehension studies (Hosoda, 2017; Ushiro et al., 2015). The text was manipulated in terms of the explicitness of causal relations by following the procedures specified in Ozuru, Briner, Best, and McNamara (2010). First, a text with implicit causal relations was created by removing connectives (e.g., *however*, *because*, and *therefore*) and replacing nouns with pronouns. A text with explicit causal relations was then created by taking the original text and (a) adding connectives, (b) replacing pronouns with corresponding noun phrases, (c) adding nouns to enhance argument overlap between sentences, and (d) adding explanatory information to clarify relations between adjacent sentences.

Two raters conducted the explicitness manipulation. When necessary, discussion was held with an English native speaker to ensure that expressions and discourse contexts were natural. Table 2 presents key text features. As shown by the number of causal connectives, the manipulation successfully increased causal connectives in the explicit condition, as relative to the implicit condition. Flesch-Kincaid grade level indicates that the explicit text was more difficult than the implicit text; this is to be expected, because this index is computed based on word length and sentence length, both of which were increased by the manipulation.

Table 2

Features of the Explicit and Implicit Texts

	Explicit	Implicit
Number of causal connectives	7	0
Flesch–Kincaid grade level	8.24	6.72
Number of words	237	188

Note. Causal connectives include *therefore,* because, and *as a result* that specify a causal relation between two clauses; specifically, the explicit-condition text had three, two, and two of *therefore, because, and as a result,* respectively; Flesch–Kincaid grade level and the number of words were computed by Word for Mac 2016.

Causal network analysis. To determine the number of CCs of each statement in the experimental text, three Japanese graduate students and I performed the causal network analysis (Millis et al., 2006; Trabasso et al., 1989). We first divided the experimental passage in the explicit and implicit version into 29 or 27 statements, respectively, with each statement corresponding to a subject-verb clause. For the causal network analysis, we then selected 22 statements that were commonly present across the explicit and implicit conditions and were relevant to the main theme of the passage. These statements specifically described a series of events occurring in the human body in space (statements in the last paragraph were not considered because they were not directly relevant to these events). We identified the presence of causal relations among statements by means of a *counter factual test*. Specifically, we followed other the causal network model studies using the criterion of logical necessity (e.g., Ushiro et al., 2015; Varnhagen, 1991). This criterion assumes a causal relation between events A and B, in that if event A had not occurred, then event B would not have occurred; event A is necessary for event B to occur. Consider Statements 6 ("While in space, the body is not affected by gravity") and 7 ("Therefore, blood and water do not travel to the lower parts of the body, especially legs."), for example. If the human body is affected by gravity, it is possible that blood and water may descend to the lower body due to gravity. Therefore, we can assume a causal relation between these two statements.

Furthermore, we used two additional criteria to define causal relations. First, a causal relation was identified between those statements that involved mediating events for their causal link (Otero, Calderia, & Gomes, 2004). Let us consider Statements 21 ("In addition, the decreased body water makes the heart pump less blood than normal.") and 24 ("As a result, the heart becomes smaller."). Between these two statements are mediating Statements of 22 and 23 ("Thus, the heart does not work" and "as hard as on Earth", respectively), which provide additional explanations for why Statement 21 leads to 24. We identified a causal relation between Statements 22 and 24 because we can assume that when the heart pumps blood normally, the heart does not shrink. Second, we did not identify causal relations between those statements that deal with essentially the same event or co-occur in situations in the text. For example, Statements 3 ("how the zero gravity of space would affect humans.") and 6 ("While in space, the body is not affected by gravity") describe the same thing. Therefore, a causal relation does not apply between them.

Using these criteria, we separately analyzed each of the 22 statements' causal relations with all the other statements in the text. Several discussions were held to resolve discrepancies. We finished the analysis when we reached agreement on causal relations for all the 22 statements. Based on the causal network analysis results, I computed the number of causal relations each statement had with prior text (i.e., CCs). Following Ushiro et al.'s (2015) procedure, statements were then grouped into low-CC (with zero to two CCs; $k = 8$), middle-CC (with three to eight CCs; $k = 7$), and high-CC statements (with nine to 15 CCs; $k = 7$). Appendix shows the experimental text (in the explicit condition) with the number of CCs.

3.3 Procedure

Participants were individually tested. At the beginning, I explained the general purpose and procedures of the study to participants and gained informed consent. Participants were assigned either the explicit or implicit text to start the reading session. In the reading session, participants were orally and visually instructed on how to read the experimental text on a PC screen. They practiced reading with one separate text. The practice and experimental texts were presented one statement at a time, left-aligned on a PC screen. After the signal “ready?”, participants’ pressing of the “yes” button on a response pad RB-730 (Cedrus, CA, USA) initiated the first statement. Participants were instructed to read for understanding so that they could complete post-reading tests (not reported in this article). After understanding the current statement, participants pressed the “yes” button, which replaced the current statement with the next one. Reading times for each statement were recorded with Super Lab 5.0 (Cedrus, CA, USA). The average time to complete the experiment was 45 minutes.

3.4 Scoring and Data Analysis

Reading times for statements were divided by the number of syllables in the corresponding statement to account for differences in statement length. Statement reading times were removed if they were less than 100 ms or three *SD*s away from the mean for a participant. This procedure resulted in the removal of 3.40% of the data.

4. Results

4.1 Reading Times for Text Statements

Table 3 shows the descriptive statistics of reading times for statements in the explicit and implicit conditions. To obtain an overall picture of the reading time results, I first computed correlations between statement reading times and the number of CCs separately for these conditions. In the explicit condition, statement reading times and the number of CCs were negatively correlated, $r = -44$, $p = .041$, meaning that there was a tendency for shorter reading times to be associated with increased numbers of CCs. On the other hand, there was no significant correlation between statement reading times and the number of CCs in the implicit condition, $r = -.10$, $p = 671$. These correlation results together indicate that patterns of statement reading times were different between the explicitness conditions.

Table 3

Statement Reading Times as a Function of the Explicitness of Causal Relations and the Number of CCs

	High-CC			Middle-CC			Low-CC		
	M	95% CI	*SD*	*M*	95% CI	*SD*	*M*	95% CI	*SD*
Explicit	558.84	[475.17, 642.50]	217.67	648.15	[515.80, 780.51]	344.34	674.28	[526.64, 821.91]	384.09
Implicit	625.76	[549.45, 702.06]	198.52	718.70	[618.79, 818.60]	259.90	619.15	[537.93, 700.37]	211.30

Next, statement reading times were subjected to a 2 (Explicitness: explicit, implicit) × 3 (CCs: high, middle, low) two-way mixed analysis of variance to examine possible effects of and a interaction between the factors. The results found a significant Explicitness × CCs interaction, which is illustrated in Figure 2, $F(2, 100) = 4.49$, $p = .014$, $\eta p^2 = .08$. A main effect of CCs was also significant, $F(2, 100) = 7.38$, $p = .001$, $\eta p^2 = .129$. Conversely, a main effect of the explicitness was not significant, $F(1, 50) = 0.14$, $p = .705$, $\eta p^2 = .01$.

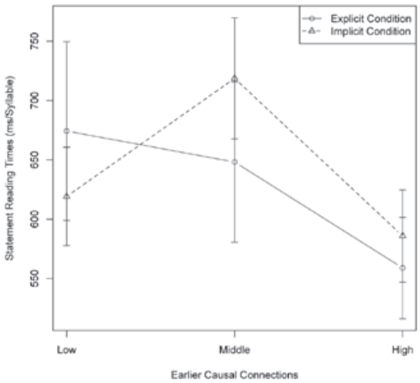

Figure 2. Statement reading times + error bars (standard errors) as a function of explicitness of causal relations and the number of CCs.

To interpret the Explicitness × CCs interaction, I performed follow-up tests with Bonferroni correction. In the explicit condition, high-CC statements elicited significantly shorter reading times than middle-, $t(25) = 2.84$, $p = .026$, $d = 0.31$, and low-CC statements, $t(25) = 2.40$, $p = .026$, $d = 0.37$. By contrast, reading times were not significantly different between low- and middle-CC statements, $t(25) = 0.80$, $p = .429$, $d = 0.07$. In the implicit condition, longest reading times were found for middle-CC statements, compared to low-, $t(25) = 3.25$, $p = .010$, $d = 0.42$, and high-CC statements, $t(25) = 3.21$, $p = .010$, $d = 0.40$. Differences between low- and high-CC statements were not significant, $t(25) = 0.25$, $p = .806$, $d = 0.03$. Finally, a simple main effect of the explicitness factor was not found for any CC statements, (all $ps > .10$), meaning that overall reading times were not affected by the explicitness of causal relations.

5. Discussion

The results confirmed an Explicitness × CCs interaction. Participants in the explicit condition read high-CC statements fastest. By contrast, participants in the implicit condition showed the longest reading times for middle-CC statements. Below, I provide separate discussions for the explicit and the implicit conditions to interpret this Explicitness × CCs interaction.

5.1 Discussion of Findings in the Explicit Condition

In the explicit condition, shorter reading times were associated with increased numbers of CCs. This result is in line with the causal network model, indicating that participants understood incoming statements by means of causal relations that those statements had to prior text. In the explicit condition, how each statement was causally related to others was overtly signaled by linguistic markers. This increased the availability of causal relations for on-line processes, resulting in the facilitation in reading times.

Of theoretical significance, this finding provides the evidence that the causal network model can be applied to on-line processes in L2 readers of expository text. Causal relations in the present expository text are scientific, physical, and less embedded in daily lives (Britten & Gülgöz, 1991) compared to causal relations in narrative text that consists of characters' goal-action relations (e.g., Trabasso & van den Broek, 1985; Trabasso et al., 1989). Apparently, making causal relations explicit can alleviate the difficulty associated with lower familiarity of expository text. This observation partly accords with studies that reported that increased text cohesion promotes comprehension in readers with low prior knowledge (e.g., McNamara, Kintsch, Songer, & Kintsch, 1996). The reason for this is that low-knowledge readers cannot fill in conceptual gaps in text by themselves (O'Reilly & McNamara, 2007). It can be assumed that the increased explicitness in the present experimental text scaffolded participants to sensitively use causal relations for on-line comprehension processes. This study accordingly confirmed that L2 readers are sensitive to scientific causal relations in expository text on condition that those relations are made explicit.

5.2 Discussion of Findings in the Implicit Condition

Participants in the implicit condition took longest to read middle-CC statements. This result does not match the prediction from the causal network model. Specifically, reading times in the implicit condition were predicted to be prolonged as a function of the number of CCs such that high-CC statements would elicit longest reading times.

A possible explanation for the present result has to do with the moderate number of CCs (three to eight) of middle-CC statements. To understand this explanation, it is helpful to consider the other statements. First, high-CC statements had an extensive number of CCs (nine to 15), which may make high-CC statements' causal relations to prior text conceptually evident. As a result, high-CC statements did not "necessitate" inference generation by participants. This view is supported by the structure of the experimental text where any given statements almost always described the outcomes of the previous statements. It seems that participants had processed a substantial number of causal antecedents to high-CC statements at the point when they encountered those statements. This increased the predictability of causal relations of high-CC statements, resulting in the facilitation for their reading times.

On the other hand, the number of CCs were quite limited for low-CC statements. Because they had a few (if not no) CCs, low-CC statements hardly "allowed" participants to engage in inferential processing. Collectively, high-CC statements did not necessitate, and low-CC statements did not allow, inferring causal relations. Only middle-CC statements that had moderate numbers of CCs both necessitated and allowed participants' inference generation. This is partly consistent with L1 studies showing that L1 readers engage in additional inference generation to understand statements with moderate strength of causal relations to preceding events (Myers et al., 1987).

In sum, the findings in the implicit condition demonstrate that L2 reading processes does not necessarily align with the causal network model. Together with the explicit condition results, it can be concluded that L2 readers implement different comprehension processes according to the explicitness of causal relations. L2 readers' such sensitivity to the explicitness of causal relation implies that more complex cognitive processes are involved in L2 text comprehension than those reported in past studies (Ushiro et al., 2010). Direct exploration into whether and to what extent L2 readers infer implicit causal relations will provide a more comprehension account of L2 expository comprehension.

6. Conclusion

This study explored whether and how L2 readers understand explicit and implicit causal relations in expository text based on the causal network model. The results show that participants sensitively understood causal relations and used them to process currently read statements when causal relations were made fully explicit. In the implicit condition, on the other hand, participants engaged in inferential processes when reading statements having moderate numbers of causal relations. The findings together indicate that L2 readers' cognitive processes associated with understanding causal relations are more complex than assumed by the causal network model. I propose that the model should additionally consider the explicitness of causal relations as a parameter so that it can better explain L2 expository comprehension processes.

The present findings also offer implications for reading instruction in educational settings. First, a theoretical discourse analysis, like the causal network model, can be used to identify where students will encounter processing difficulty in the text. Based on the information from the text analysis, students can be reminded of when or where they should pay attention so that they can effectively tackle the difficult parts of the text. For example, this study found that middle-CC statements elicited inference generation when causal relations are implicit. It is advised that interventions should be given for confirming students' causal comprehension of information with moderate numbers of CCs. In addition, teachers can assess the extent of students' inferential comprehension by causally questioning statements with moderate numbers of CCs. Why-type inference questions are useful for this purpose (e.g., Why is it difficult for the human body to work normally in space?).

Second, this study found that L2 students can use linguistic markers (e.g., connectives, pronouns) to guide their causal understanding, as reflected by the fact that participants were sensitive to causal relations in the explicit condition. Increasing the explicitness of causal relations is an effective way of supporting L2 students' causal comprehension. Past studies showed that increased cohesion is effective for low-knowledge readers (McNamara et al., 1996). Making causal relations in expository text explicit would thus scaffold begging learners to learning from text.

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Appendix:

An Experimental Text (in the Explicit Condition) and the Number of CC

Statements 9 and 18's causal relations were not computed because they were not included in the implicit-condition text.

	Statement	The number of CCs	CC Group
1	When people first considered space travel	0	Low
2	they did not know	0	Low
3	**how the zero gravity of space would affect humans.**	0	Low
4	The human body is a complex system	0	Low
5	**that automatically responds to the lack of gravity**	1	Low
6	**While in space, the body is not affected by gravity.**	0	Low
7	Therefore, blood and water do not travel to the lower parts of the body, especially the legs.	2	Middle
8	**Therefore, blood and water do not travel to the lower parts of the body, especially the legs.**	3	Middle
9	Because the blood and water travel to the upper parts of the body,		
10	the body feels	4	Middle
11	**like the chest and head are filled with blood and water.**	4	Middle
12	Because of this, the heart and lungs send messages	4	Middle
13	that the amount of blood and water in the upper part of the body must be reduced.	6	High
14	As a result, space travelers do not feel thirsty,	8	High
15	**and therefore, space travelers drink less water.**	9	High
16	As body water is eliminated,	10	High
17	**their body water levels become lower than normal.**	11	High
18	When the amounts of blood and water decrease,		
19	it becomes more difficult for the human body	11	High
20	**to work normally.**	3	Middle

21	In addition, the decreased body water makes the heart pumps less blood than normal.	11	High
22	Therefore, the heart does not need to work	13	High
23	as hard as it does on Earth.	2	Middle
24	**As a result, the heart becomes smaller.**	15	High