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Improving Health Literacy of Domestic Household Disinfection Use: Readability of Consumer-Facing Information on Domestic Household Disinfectant Products on Sale in the UK—An Infodemiology Study

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Abstract: Disinfectants purchased from retail outlets form the cornerstone of infection control and prevention within the domestic household. The growing utilisation of the concept of "hospital-at-home" places greater emphasis on domestic disinfection by the householder in helping to prevent the acquisition of infections within the home. No reports or data exist that indicate how readable the information provided on disinfectants is, which would help householders use disinfectants optimally. The aim of this study was therefore to quantitatively examine the readability (Flesch Reading Ease; Flesch–Kinkaid Grade Level; text metrics) of consumer (public)-facing information (n = 108) of domestic household disinfectants sourced from (i) UK high street supermarket chains (n = 4) and (ii) disinfectant manufacturers (n = 6). The readability of all supermarket and manufacturer information (n = 108) gave a mean Flesch Reading Ease score of 51.7 (target $\geq$ 60) and a Flesch–Kinkaid Grade Level score of 8.1 (target $\leq$ 8), thereby failing to achieve readability reference target values. Authors preparing information on the domestic use of disinfectants should be aware of the value of quantitative readability metrics and online tools to help support their writing of such information in order to produce materials which are within target readability values, thereby further supporting health literacy in this population and disinfectant efficacy.

Keywords: biocide; COVID-19; disinfectant; health literacy; readability; supermarket

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1. Introduction

The COVID-19 pandemic of 2020 precipitated a home hygiene boom which created an unprecedented demand for household disinfectants and home hygiene products to sanitise domestic homes during periods of lockdown in an attempt to prevent the survival and spread of the SARS-CoV-2 virus. During this time, worldwide sales of such products grew by 47% to USD 4.1 billion and sales of aerosol disinfectants in particular grew by nearly 400 percent [1]. Historically, disinfectants have been considered to be effective chemical agents that destroy disease-causing pathogens or other harmful microorganisms but might not kill bacterial spores [2]. Several factors have been documented to alter the effectiveness of disinfectants, including (i) the number and location of target pathogens, (ii) the innate resistance of pathogens, (iii) the concentration and potency of disinfectants, (iv) physical and chemical factors, (v) biofilms, (vi) the presence of organic and inorganic material and (vii) the duration of exposure [2]. Therefore, the correct and appropriate application of household disinfectants for the optimal removal of pathogens within the home requires a reasonable understanding of how to correctly employ the disinfectant of the user within the home. Several reports have been published describing the role of household disinfectants during the pandemic [3,4]. One recent study from Abu Dhabi in the United Arab Emirates assessed public levels of awareness and performance concerning

the safe use of household cleaning products and disinfectants during COVID-19. The results showed that the majority of survey respondents reported at least one adverse event associated with the use of disinfectants, ranging from skin irritation to poisoning, and significant differences in awareness and performance mean scores among various educational levels ($p < 0.001$) as well as the level of performance between males and females ($p < 0.001$) [4]. Additionally, studies from Italy and China showed toxicological events due to the mishandling of disinfectants [5,6]. These reports collectively suggest that there was some degree of a lack of understanding in the general public as to how household disinfectants work.

Readability can be assessed through a range of quantitative readability parameters and formulae based on various text metrics such as word count, sentence count and syllables [7]. Some readability formulae commonly used in healthcare include the Flesch–Kinkaid Grade Level (FKGL) and the Flesch Reading Ease (FRE) scores [7]. If the consumer information which accompanies these household products is poor, then the consumer may be less likely to understand how to use these products correctly, which may result in them not being used properly. A good understanding of how to use these products is vital to maximise disinfectant efficacy.

To date, there have been no reports describing the readability of domestic household disinfectant instructions. The aim of this study was therefore to examine the readability (Flesch Reading Ease, Flesch–Kinkaid Grade Level, Gunning Fog and SMOG scores; text metrics) of consumer-facing information with domestic household disinfectants sourced from (i) UK high street supermarkets and (ii) disinfectant manufacturers in order to establish:

(i) How readable such information is for the general public against readability reference standards;
(ii) If there are differences in readability between information provided by supermarkets and that provided by disinfectant manufacturers.

2. Materials and Methods

An overview of the methods employed is shown in Figure 1.

2.1. Retrieval of Disinfection Information

Consumer (public)-facing information on domestic household disinfectants currently on sale in the UK was selected for investigation (n = 108). This included products for surface and floor disinfection, including sprays, aerosols, wipes and solutions. All products were identified as household disinfectants and were on retail sale in the UK in October 2023. Information was obtained from two different sources, namely (i) four UK high street supermarket companies/chains (Supermarket A, B, C and D), with a combined market share of 61.8% of the UK market, which commercially sell such products to consumers/general public (n = 74 product information) and (ii) manufacturers of six leading UK household disinfectants (Disinfectants A–F) (n = 34 product information). All information was obtained freely from online sources for supermarkets and manufacturers in the public domain.

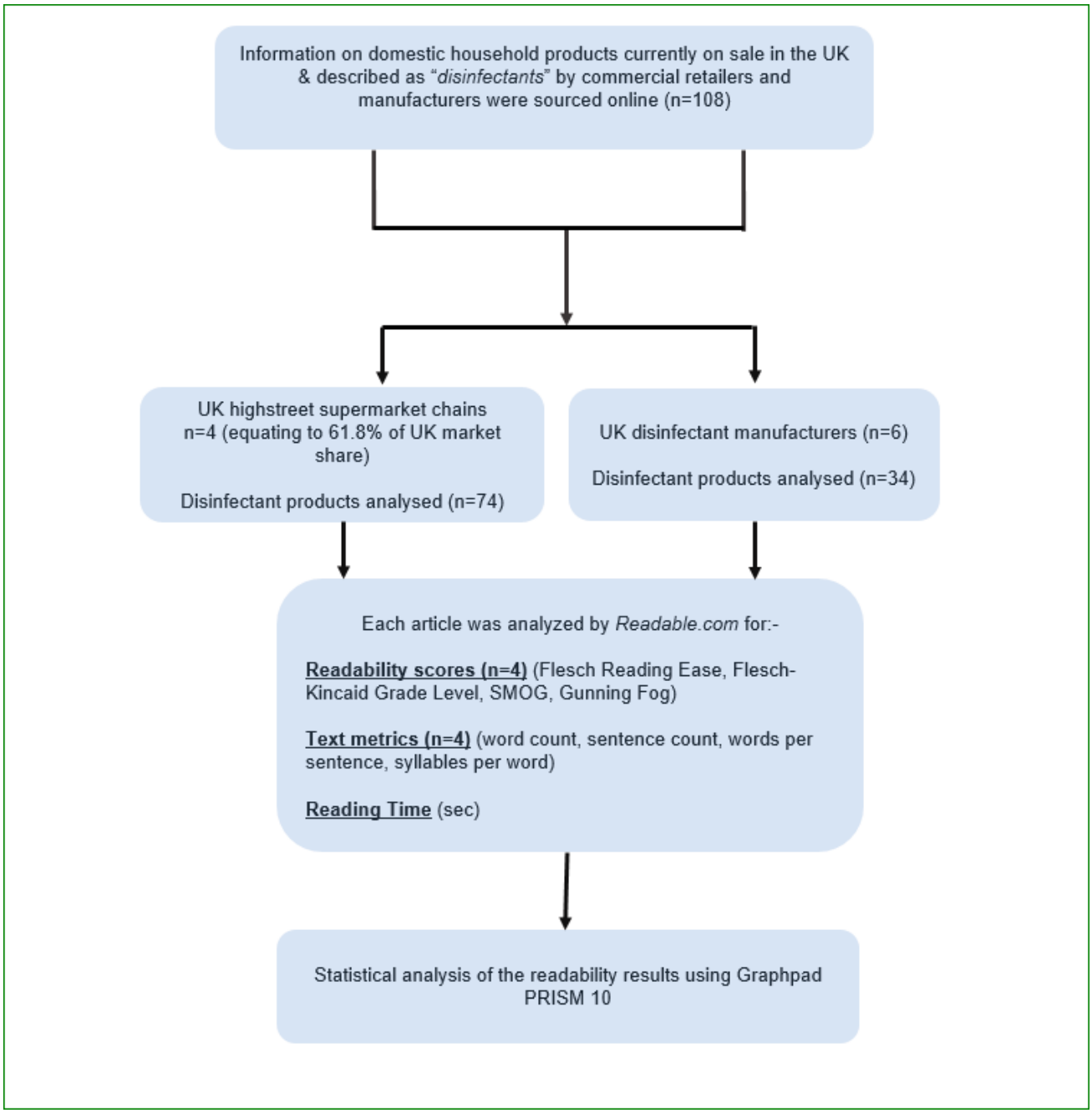

Figure 1. Flow diagram of methodological investigations undertaken in this study.

2.2. Determination of Readability Scores and Text Metrics

Each source of disinfection information was examined using the online subscription-based software tool, *Readable* (www.readable.com, accessed on 19 October 2023), which was used in accordance with the website's instructions. The software was used to calculate four readability scores, including (i) Flesch Reading Ease, (ii) Flesch–Kinkaid Grade Level, (iii) the Gunning Fog Index and (iv) the SMOG Index, as detailed in Supplementary File S1. An additional four text metrics were also calculated, including word count, sentence count, words per sentence and syllables per word. The reading time for each information source was also recorded. These readability measures were chosen for examination as most readability studies employ and quote the results of these. Readable.com was selected as the preferred online calculator, as it has been previously used in several healthcare readability studies, as well as in a recent study which compared a variety of online readability calculators and con-

cluded that *Readable* was the optimum calculator to use due to its accuracy, user experience and capacity to examine multiple readability parameters from clinical materials [8].

Target (reference) values for both the Flesch Reading Ease and the Flesch Kinkaid Grade Level were previously described by Badarudeen and Sabharwal [7], as well as defined by the Readable software.

2.3. Statistical Analyses

The readability data obtained underwent statistical analyses using GraphPad PRISM version 10 (Boston, MA, USA). To determine if the data followed a normal distribution, a normality test was performed on each set of data using the Shapiro–Wilk test. Depending on the normality of data distribution, for data that were normally distributed, one-way ANOVA (parametric) was performed, with a post hoc Tukey multiple-comparisons test, to compare the means of normally distributed parameters. For data sets that were not normally distributed, the Kruskal–Wallis (non-parametric) test with Dunn's adjusted p values was performed. A p value of < 0.05 (5%) was considered as statistically significant.

3. Results

This study captured the majority of disinfectant products which were available and on sale to the general public and consumers. Duplicate entries were avoided within each retailer, i.e., for the same product offered in 250 mL, 500 mL and 1 L quantities. The inclusion criteria included if the retailer or manufacturer labelled the product as a "disinfectant".

The readability of all supermarket and leading brand information on disinfectants (n = 108) is shown (Table 1). A comparison of the Flesh Reading Ease and Flesch Kinkaid Grade Level for all disinfectant information sources (n = 108) against readability reference standards is shown in Figure 2. A comparison of readability and text metric scores between supermarkets and leading brand manufacturers are shown in Figures 3 and 4, respectively. A comparison of the reading time (sec) between supermarket- and manufacturer-provided information is shown (Figure 5). There was no significant difference between information provided by Supermarkets A—D in relation to the Flesch Reading Ease score and only one significant difference between Supermarket A and Supermarket C ($p = 0.0048$) in relation to the Flesch Kinkaid Grade Level. There was only one significant difference between the Flesch Reading Ease score and two of the leading disinfectant brands (Brand C and Brand D) ($p = 0.0386$).

Table 1. Descriptive statistics relating to the readability of 108 sources of information on disinfectants from UK supermarket chains and manufacturers.

	Flesch Reading Ease	Flesch Kinkaid Grade Level	Gunning Fog Score	SMOG Score	Total Words	Number of Sentences	Words per Sentence	Syllables per Word	Reading Time (s)
Minimum	34.0	4.5	3.0	6.5	58.0	5.0	3.8	1.4	15.0
25% Percentile	48.3	7.4	7.0	9.3	251.0	32.0	6.5	1.7	70.0
Median	51.7	8.0	8.0	9.9	367.0	47.0	7.8	1.7	98.0
75% Percentile	55.0	8.7	9.2	10.7	465.3	65.8	9.2	1.8	127.5
Maximum	77.3	12.5	13.7	13.2	1832	184.0	22.8	2.0	488.0
Range	43.3	8.0	10.7	6.7	1774	179.0	19.0	0.6	473.0
Mean	51.7	8.1	8.1	10.1	378.9	49.2	8.3	1.7	102.1
Std. Deviation	7.4	1.2	1.8	1.2	212.1	25.5	3.0	0.1	56.7
Std. Error of Mean	0.7	0.1	0.2	0.1	20.4	2.5	0.3	0.0	5.5

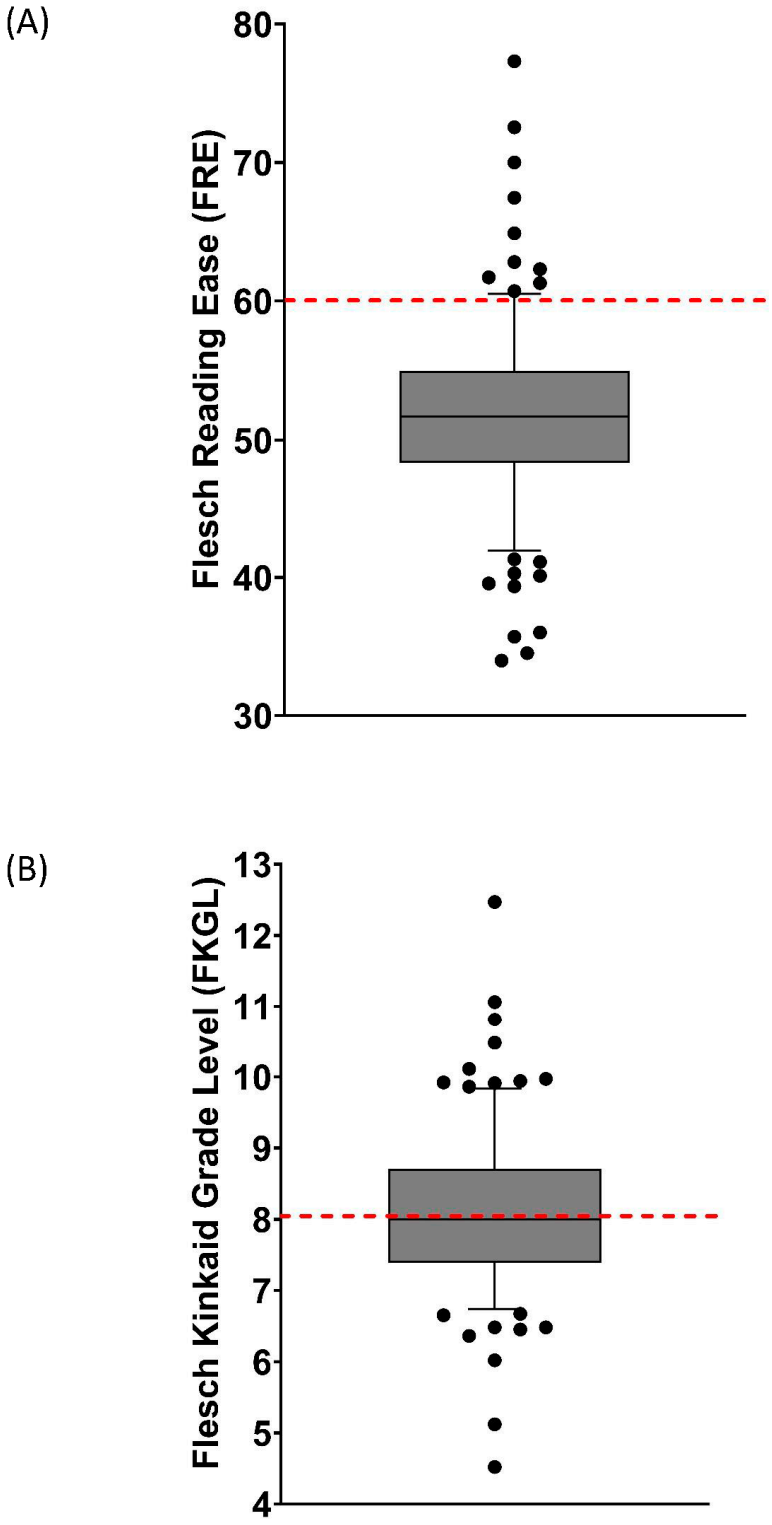

Figure 2. Box and whiskers plot comparing readability scores for (**A**) Flesch Reading Ease and (**B**) Flesch–Kinkaid Grade Level for total information sources examined (n = 108). Box represents 25th and 75th percentiles and bar represent the median. Whiskers represent the 10th and 90th percentiles and • represents outliers outside these percentile ranges. The dashed red line represents the target readability score. For the Flesch Reading Ease, this is ≥60. For the Flesch–Kinkaid Grade Level, this is ≤8.

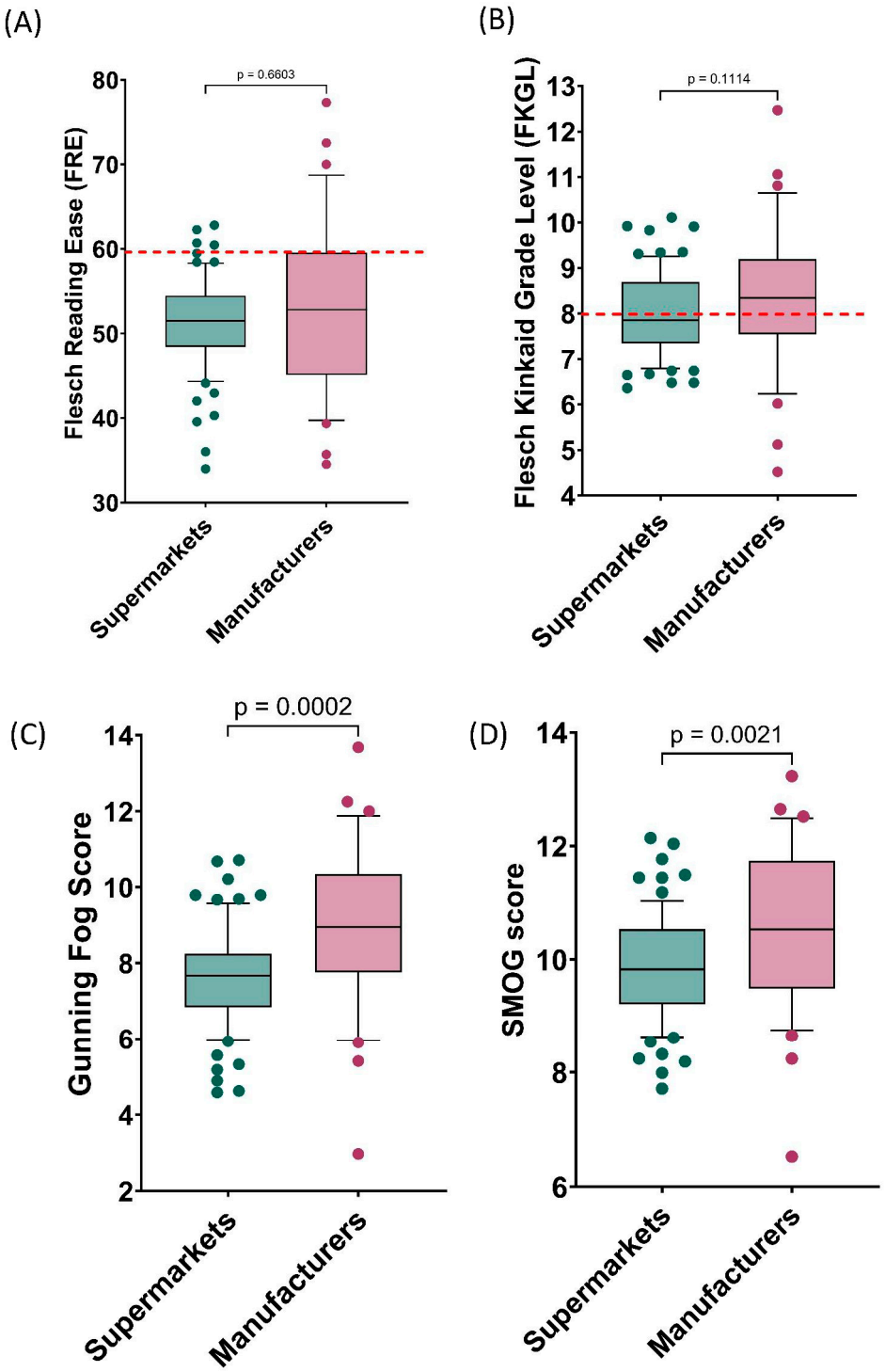

Figure 3. Box and whiskers plot comparing readability scores for (**A**) Flesch Reading Ease; (**B**) Flesch–Kinkaid Grade Level; (**C**) Gunning Fog score; and (**D**) SMOG score. These were calculated from (i) supermarket-provided information (n = 74) and (ii) manufacturer-provided information (n = 34) on disinfectants on retail sale in the UK in September 2023. Box represents 25th and 75th percentiles and bar represent the median. Whiskers represent the 10th and 90th percentiles and • represents outliers outside these percentile ranges. Statistical significance is shown, as calculated using an unpaired *t* test for data which had a normal distribution (parametric) and a Mann–Whitney test for data which had a non-normal distribution (non-parametric). A *p* value of <0.05 (5%) was considered as statistically significant. The dashed red line represents the target readability score. For the Flesch Reading Ease, this is ≥60. For the other scores, this is ≤8.

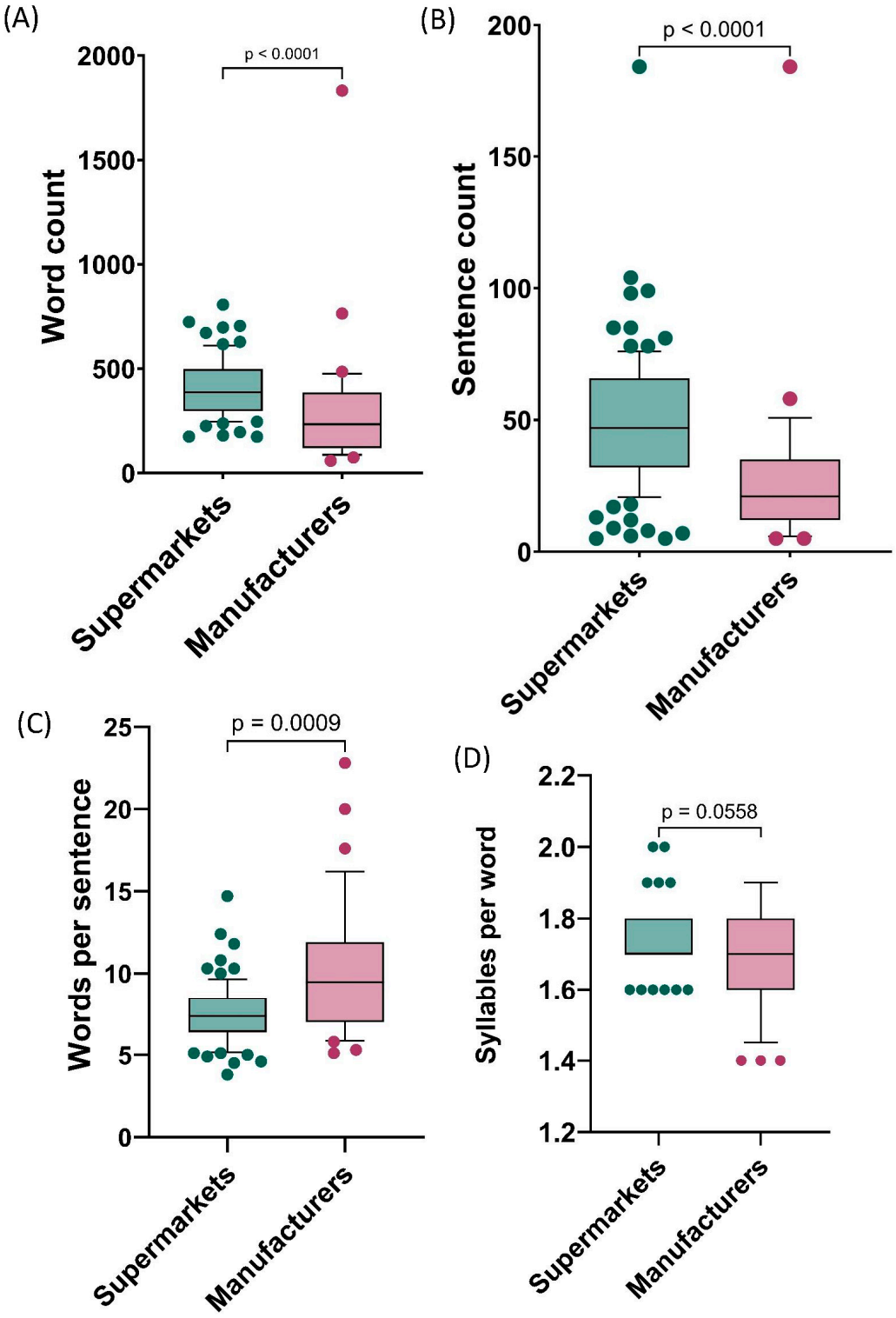

Figure 4. Box and whiskers plot comparing the text metric scores readability scores for (**A**) word count; (**B**) sentence count; (**C**) words per sentence; and (**D**) syllables per word scores. These were calculated from (i) supermarket-provided information (n = 74) and (ii) manufacturer-provided information (n = 34) on disinfectants on retail sale in the UK in September 2023. Box represents 25th and 75th percentiles and bar represent the median. Whiskers represent the 10th and 90th percentiles and • represents outliers outside these percentile ranges. Statistical significance is shown, as calculated using an unpaired *t* test for data which had a normal distribution (parametric) and a Mann–Whitney test for data which had a non-normal distribution (non-parametric). A p value of <0.05 (5%) was considered as statistically significant.

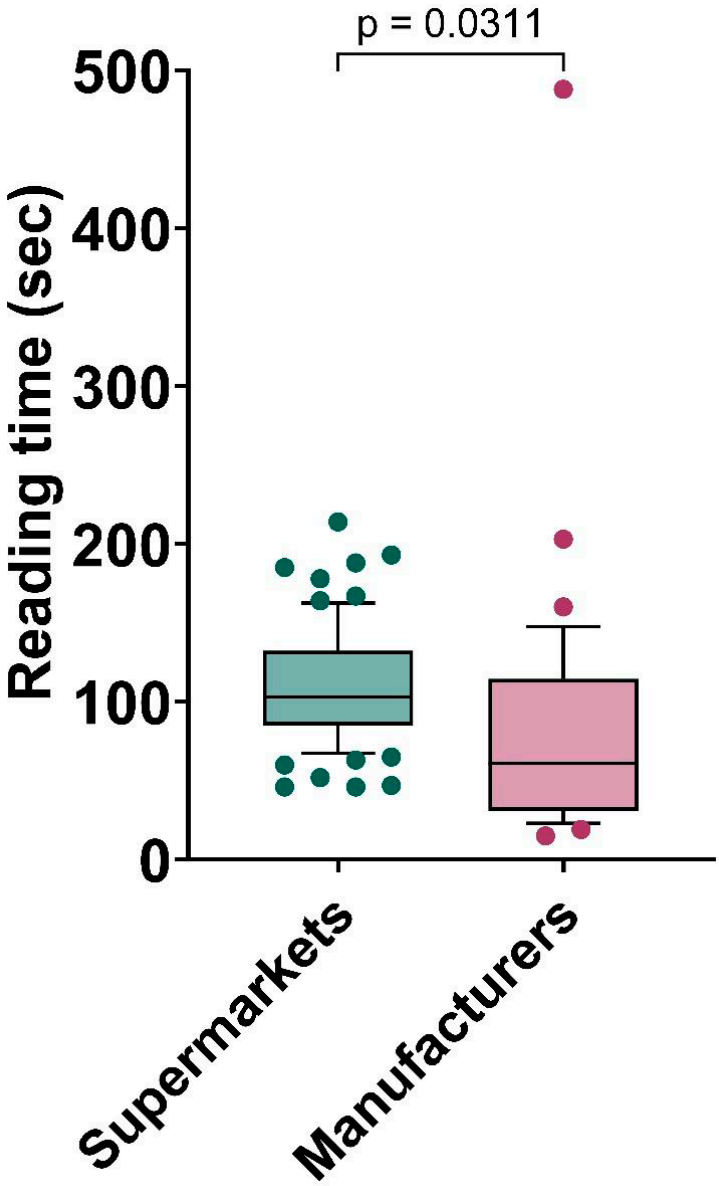

Figure 5. Box and whiskers plot comparing reading time (secs) for disinfectant information provided by (i) supermarkets (n = 74) and (ii) manufacturers (n = 34) on retail sale in the UK in September 2023. Box represents 25th and 75th percentiles and bar represent the median. Whiskers represent the 10th and 90th percentiles and • represents outliers outside these percentile ranges. Statistical significance is shown, as calculated using an unpaired *t* test for data which had a normal distribution (parametric) and a Mann–Whitney test for data which had a non-normal distribution (non-parametric). A *p* value of <0.05 (5%) was considered as statistically significant.

Overall, when collectively considering the information provided by these two sources, reference readability scores were not achieved, as the mean Flesh Reading Ease score was 51.7 (target $\geq$ 60) and the Flesch Kinkaid Grade Level score was 8.1 (target $\leq$ 8) (Table 1). When evaluated as separate sources of information, there was no significant difference in the FRE and FKGL scores between supermarkets and manufacturers (Figure 3A,B). However, both the Gunning Fog and SMOG scores showed better readability for supermarket-provided information (p = 0.0002 and p = 0.0021, respectively) (Figure 3C,D). With regard to text metrics, supermarkets prepared information which was significantly longer in length in terms of word count and sentence count ($p < 0.0001$ and $p < 0.0001$) (Figure 4A,B). More importantly, supermarkets prepared materials which

had significantly fewer words per sentence (p = 0.0009), which is crucial for improved readability (Figure 4C). The consequence of the longer word counts and sentence counts found for supermarket-provided information was a significantly longer reading time (p = 0.0311).

4. Discussion

Disinfectants purchased from UK retail outlets, particularly supermarkets, form the cornerstone of infection control and prevention within the domestic household. The significance of this is heightened when the household includes someone who is immunocompromised or immunosuppressed due to disease or medical treatment. Additionally, the growing utilisation of the concept of "hospital-at-home" places a greater emphasis on domestic disinfection by the householder in preventing the acquisition of infections from within the household and the spread of infection from the patient to other members of the household and and vice versa.

In these situations, it is important that the user of retail-purchased disinfectants has an adequate understanding of how to use the disinfectant properly to achieve the optimal effect of the disinfectant. In a recent seminal review on the mechanisms of action of disinfectants and disinfectant resistance by Maillard and Pascoe [2], the authors list 14 extrinsic factors affecting the performance of biocides. Many of these factors lie outside the control of domestic users of disinfectants, including the mechanism of action of the disinfectant, formulation and product composition, the presence of endospores and bacterial type. However, the majority of these factors do lie within the control of domestic users of disinfectants, including concentration, contact time, the presence of organic soil, surface type, temperature, method of delivery and interaction between the biocide and applicator. For this reason, it is important that the domestic user has good health literacy regarding the consequences of not only mishandling and misusing disinfectants, in terms of disinfectant efficacy against target pathogens, but also from a health and safety perspective. At a functional health literacy level [9], communication of information to domestic householders is critical, as such information improves the knowledge of how best to use such chemicals, and such information provides a reference point for judging compliance with the prescribed use, as described by the manufacturer. The responsibility of the provision of information lies with the manufacturer of the disinfectant, as well as with the retailer of such products. Our study's aim was to investigate the readability of information provided by supermarkets and manufacturers in the UK.

4.1. Support for Authors Preparing Information on Disinfectants

Table 2 provides several resources and tools that may help support authors in the writing of information on disinfectants with improved readability.

Table 2. Help, support and resources for authors to aid in the writing of information on disinfectants with improved readability.

Description	Author(s)	Web Address
Simply put; a guide for creating easy-to-understand materials	Centers for Disease Control & Prevention (USA)	https://www.cdc.gov/healthliteracy/pdf/simply_put.pdf (accessed on 19 October 2023)
Online readability tutor and calculator	Readable.com	www.readable.com (accessed on 19 October 2023)
Improved readability toolkit and checklist	Anderson H, Moore JE & Millar BC	DOI: https://doi.org/10.1016/j.jcf.2021.09.009 (accessed on 19 October 2023)

4.2. Study Limitations

We performed an up-to-date literature search on PubMed (https://pubmed.ncbi.nlm.nih.gov/ accessed on 19 October 2023) using the keywords "disinfectant", "literacy",

"health literacy" and "readability" and were unable to retrieve any reports. Widening the search to non-academic sources may have yielded more data. The results of our searches and the outcomes of the current study identify important knowledge gaps and opportunities to intervene to improve householder health literacy on the use of disinfects within the home environment. In addition, it would be interesting to compare UK data with data from other English-speaking countries, including the US, Australia and New Zealand, to establish if there is a difference between countries with regard to how well each nation presents readable text. It is important to make use of all available media and modalities to drive greater readability and understanding with regard to how consumers use disinfectants to maximise the microbiological destruction of pathogens and hence enhance the value of the product. The adoption and employment of figures and iconography may further help with increasing consumer understanding of how best to use disinfectants.

In conclusion, the mean readability scores relating to information on disinfectants, from both supermarkets and manufacturers, did not achieve the reference target values. Moving forward, authors preparing information on the domestic use of disinfectants should be aware of the value of using quantitative readability metrics and online tools when writing such information for domestic readers in order to produce materials which are within the target readability values, thereby further supporting the health literacy of this population and disinfectant efficacy.

Supplementary Materials: The following are available online at: https://www.mdpi.com/article/10.3390/hygiene3040036/s1: supplementary file (S1): Summary table of readability formulae used in this study and their associated target scores (for the general public).

Author Contributions: J.E.M.: conceptualisation; formal analysis; methodology; roles/writing—original draft; writing—review and editing. B.C.M.: conceptualization; formal analysis; methodology; roles/writing—original draft; writing—review and editing. All authors have read and agreed to the published version of the manuscript.

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Informed Consent Statement: Not applicable.

Data Availability Statement: Data is contained within the article or supplementary material.

Conflicts of Interest: The authors declare that the research was conducted in the absence of any commercial, financial or other relationships that could be construed as a potential conflict of interest.

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