EXPLORATORY ANALYSIS OF CONSUMERS' NAIVE PERCEPTION OF THE ENTROPY ASSOCIATED WITH PACKAGING MATERIALS

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Abstract: Consumers are increasingly aware of environmental issues and are reusing their packaging. This paper uses the concept of the perceived entropy of packaging to analyse the factors influencing its reuse. We propose that consumers naively perceive the level of entropy of a packaging and that this perception is influenced by its material. We conducted an exploratory study using 10 semi-structured interviews. Firstly, the results show that consumers spontaneously perceive the physical dimensions of packaging entropy. Secondly, depending on the packaging material, respondents do not rely on the same cues to perceive entropy.

Keywords: *Packaging, entropy, material*

Track: *Consumer Behavior*

Appendix

Table 1 : Participants' profiles

Participant	Gender	Age	Household Size	Occupation	Interview Duration
Magalie	W	48	5 people	Civil servant	1h 07min
Delphine	W	40	4 people	Professional coach	1h 22min
Karine	W	51	4 people	Accounting and logistics	1h 05min
Christelle	W	52	3 people	Cleaning agent	44min
Serge	M	71	2 people	Retired	1h 16min
Jocelyne	W	68	2 people	Retired	1h 16min
Chloé	W	31	2 people	Self-employed	1h 02min
Marc	M	60	2 people	Retired	1h 07min
Laurence	W	62	2 people	Retired	1h 07min
Rose-Marie	W	61	1 people	Retired	46min
Dominique	W	70	1 people	Retired	1h 22min
Bilal	M	24	1 people	Bank advisor	32min

Table 2 : Dimensions of entropy identified in the semi-structured interviews

Facets of entropy	Definition	Examples
Statistical Entropy	Statistical entropy can be defined as a measure of the disorder or progressive degradation of the packaging's physical characteristics (microstates), such as cracks, wear or yellowing. These micro-alterations influence consumers' perception of the overall state (macro-states) of the packaging.	**Microstates**: 1) 'Sometimes, without paying attention, they can pierce or break underneath, a small crack and then, well, I don't know, they can leak and so on. So that's usually when I replace them. Bilal (Male, 24). 2) 'Well, let's just say they had yellowed, um... inside they were starting to taste...'. Jocelyne (Woman, 68). 3) 'What makes iron cans like this go bad is that you wash them a lot... and... well, sometimes a spot of rust appears in a corner somewhere.' Serge (Male, 71). **Macrostates**: 1) 'Well, marks on the bottom, dirt that doesn't come off... yeah, that would be a bit of the wear and tear that needs to change, the ageing of the box.' Chloé (Female, 31). 2) 'Broken or cracked, I've got one, I realised when I put something in it that it was leaking, or someone put a knife in it and it cut it...'. Rose-Marie (Female, 61). 3) 'Yes, well, that's it. Jam jars, for example, if I buy one, I'm going to keep it to make my jams because I make quite a lot, I'm going to reuse it that's it, several times...'. Laurence (Female, 62).
Energy quality (exergy) and system stability	Entropy reflects the way in which the quality and stability of a packaging change over the course of its use. Quality is associated with the packaging's ability to continue to perform its functions, such as preserving the contents. Stability is closely linked to quality and refers to characteristics such as hermeticity and protection against environmental contamination.	**Energy quality**: 1) In iron tins, it keeps for a very very long time, like in plastic tins for sugar, things like that... she's old my sugar tin!' Serge (Male, 71). 2) 'It's better preserved in metal than in plastic!' Laurence (Female, 62). 3) 'If I want to keep them for a long time, I don't put them in plastic. Dominique (Female, 70). 4) 'I wouldn't put it in plastic, first of all I can't because the product would deteriorate, nah nah, it's only glass.' Christelle (Female, 52). **Stability of the system**: 1) 'And... plastic I don't know why I don't really like it, I'm always afraid that it will get into the food, I always have this resistance. I'm more comfortable with glass' Delphine (Female, 40) 2) 'Yes, but what I mean is that it's still alive, it absorbs humidity, it absorbs smells...'. Delphine (Female, 40). 3) 'Well, it's plastic, it gives a taste to put things in it, it's not easy'. Jocelyne (Woman, 68). 4) 'I find that wood gives a taste. So I don't think I'd put food in wooden boxes.' Magalie (Female, 48)

Table 3 : Matrix coding of nodes

Nodes	Wood			Metal			Plastic			Glass		
	Sources	Ref.	(%)	Sources	Ref.	(%)	Sources	Ref.	(%)	Sources	Ref.	(%)
STATISTICAL ENTROPY												
Macrostates			**33**			**70**			**69**			**69**
Overall condition of the packaging	2	3	33	10	69	70	10	103	69	10	75	69
Microstates			**67**			**30**			**31**			**31**
Changes in shape	2	2	22	7	10	10	6	15	10	9	20	19
Surface/texture changes	3	4	44	8	19	19	9	31	21	7	13	12
Nb. Of references		*9*			*98*			*149*			*108*	
ENERGY QUALITY AND SYSTEM STABILITY												
Energy quality			**35**			**61**			**52**			**57**
Storage capacity	1	1	3	6	11	5	6	16	4	6	13	5
Discussion on the potential of packaging	3	7	18	10	62	28	10	92	24	10	72	27
(1) Change of use/content	1	1	3	5	9	4	8	19	5	8	14	5
(2) Reasons why it has potential	1	2	5	10	52	24	10	65	17	10	52	19
(3) Reasons why it no longer has any potential	2	3	8	1	1	0	4	5	1	2	2	1
Stability of the container/content system			**45**			**25**			**31**			**27**
Exchanges between container and content	3	3	9	6	13	7	10	38	12	5	13	6
(1) Contamination of the container by the content	2	2	6	5	9	5	6	8	10	2	3	1
(2) Contamination of the contents by the container	1	1	3	3	4	2	9	30	10	4	10	4
Packaging degradation	4	8	20	9	31	14	10	64	17	10	43	16
Exchanges between the environment and the system	5	12	30	8	29	13	10	41	11	10	46	17
Nb. Of references		40			221			378			268	
TOTAL REFERENCES		49			319			527			376	

1. Introduction

'*Yes, but what I mean is that it lives on all the same, it soaks up the moisture, it soaks up the smells* ...' is how Delphine, a participant in our research, talks about the wooden packaging she has chosen to keep to store her tea bags. The material of the packaging influences the perception of the product it contains: its taste (Krishna & Morrin, 2008), its quality (Koutsimanis & al., 2012), confidence in the product (Aday & Yener, 2014), or even its ecological virtues (Sokolova & al., 2023). However, past research has not considered the fact that packaging, depending on its material, can be reused to store when the product is consumed. Our paper aims to explore the impact of packaging material on the perception of this same packaging beyond the consumption of the initially packaged product.

To understand how the packaging material is perceived once the product has been consumed, we opt for a conception of packaging as a physical system made up of a container and a content whose potential the consumer will conceive via the concept of entropy. In physics, entropy describes the level of disorder in a system (Marquet, 2019) and its capacity to provide energy (Dewulf & al., 2008). In marketing, Biliciler and colleagues (2022) have shown that consumers perceive the entropy of an advertising image 'naively' (i.e. spontaneously). An image with high entropy, representing a disordered environment, encourages the observer to project himself into the past and encourages the purchase of retro-marketing products. Conversely, a low-entropy image, representing an ordered situation, directs the observer towards the future and encourages the purchase of technological products. In this paper, we propose that consumers naively perceive the level of entropy that a package communicates via its material. Indeed, the concept of entropy in physics is strongly linked to the materials that make up the system and the way in which they are organised. Consequently, the material of a package should influence the entropy perceived by the consumer. To explore this question, and isolate the dimensions of perceived packaging entropy, we are conducting a study via 10 semi-structured interviews to analyse participants' perceptions of the packaging they have retained after the product initially contained has been consumed.

2. Theoretical Framework

2.1 Entropy and Energy Quality

Entropy, derived from thermodynamics, represents the level of disorder in a physical system (Marquet, 2019). A physical system is an element in space made up of a large number of particles, such as atoms, ions and molecules, which can be characterised by statistical quantities such as volume, temperature and pressure (Boccara, 1968). The higher the level of entropy in a system, the more energy is dispersed and the less work the system can do (the energy is less 'usable'). Usable energy is called 'exergy' by several authors (Romero & Linares, 2014) and is a measure of the quality of energy and its potential to do work (Dewulf & al., 2008; Som & Datta, 2008). An isolated system sees its entropy level increase spontaneously towards its maximum and towards a final state of equilibrium. The literature states that entropy can decrease in the case of a non-isolated system, but only at the cost of an increase in the entropy of the external environment (Marquet, 2019). Thus, by definition, the entropy of the Universe is irreversible, because the Universe is made up of all systems, but the entropy of any system is reversible.

2.2 Entropy in Statistical Thermodynamics

Statistical thermodynamics shows that the molecules in a physical system tend to be distributed randomly according to their energies (Dahan-Gaida, 1991). It indicates that each particle in a system can exist in different states, and that these states depend on the position, speed or amount of energy of this particle. Each configuration in the system is then called a ‘microscopic state’. As a result, a system can also be described by a ‘macroscopic state’, such as its temperature or volume. This ‘macroscopic state’ can be realised by a large number of different ‘microstates’, indicating that there are several ways in which particles can be arranged to produce the same observable state (e.g. the same temperature). Entropy represents the number of possible ‘microstates’ of a system, and the greater the number of possible microstates, the higher the entropy. Moreover, a material is seen as a physical system, and its level of entropy can also be measured as a function of the number of possible configurations that its atoms can take on. Entropy influences the behaviour of matter (from solid to liquid or from liquid to gas). Previous research has focused on the entropy of materials since 2004 (Cantor & al., 2004; J. -W. Yeh & al., 2004) because materials with a high entropy level, such as alloys (George & Ritchie, 2022; J.-W. Yeh, 2006), offer numerous advantages such as super conductivity and increased strength (Sarker & al., 2018).

In the context of our study on packaging, we propose to interpret entropy as an indicator enabling consumers to assess the state of their packaging, which is seen as a physical system comprising a container and contents. In other words, the degree of entropy of packaging could increase and its exergy decrease as it is used and interacts with various factors such as changes in content or the gradual appearance of wear marks linked to repeated use and exposure to external conditions. This same level of entropy, as physics would suggest, could be reversible and reduced by cleaning the packaging. We suggest that the diversity of the packaging's microstates increases with the number of times it is reused, notably because of signs of wear and tear such as yellowing, scratches or rust. However, the perception of this level of entropy varies according to the packaging material.

2.3 Link between Physical Entropy and Packaging Entropy

Previous marketing research has already mobilised the concept of entropy in the field of communication, showing that advertisers can influence the perception of products by playing on the entropy levels of the images used. A ‘low entropy image’ invites the consumer to imagine the future scenarios that could result from this image, while a ‘high entropy image’ prompts them to question the past events that led to this situation (Biliciler et al., 2022). We propose that packaging is perceived by consumers as a physical system made up of a container and a content whose potential the consumer will automatically conceive via the concept of entropy.

In particular, the packaging material communicates a level of entropy. As mentioned previously, research in thermodynamics has shown the importance of the material that makes up the system in understanding entropy. We therefore propose that the nature of the material and its state form the basis of the perceived entropy of a package. To this end, we consider the perception of packaging that consumers reuse (Ertz et al., 2017). This choice makes it possible to consider the effect of the packaging independently of its initial contents, whereas past research has focused on the influence of the packaging material on its contents.

3. **Method**

To study packaging entropy in greater depth, we opted for a qualitative approach based on ten semi-structured interviews conducted between May and October 2024 with participants. In order to elicit in-depth responses, we used several stimuli. Firstly, we asked the participants to show us the packaging they reused on a daily basis. Pictures of the packaging taken with an instant camera were used to support the discussion (Harper, 2002). Secondly, two pairs of packages, similar in use but different in material (plastic vs metal), were presented to explore perceptions of materials. Twelve people with varied profiles (see Table 1) were interviewed. (M^{age} = 53.2years old; $_{\%Women}$ = 75%). An interview guide structured around three themes was used. The first explored participants' packaging reuse habits, focusing on the reasons and criteria guiding this practice. The second theme looked at the packaging that was not reused and the reasons behind this. Finally, the last theme proposed a discussion on the two pairs of packs brought in by the researchers, focusing on the perception of the materials. The questions were adjusted over the course of the interviews to improve their quality.

The interviews were recorded in their entirety, transcribed and analysed using thematic content analysis using Nvivo 14 software. The verbatims were classified in such a way as to link them with the different facets of entropy naively perceived by the participants, and also according to the material they dealt with. This enabled us to produce a matrix coding (see Table 2) linking the facets of entropy used to the packaging materials.

4. **Results**

4.1 The perception of statistical entropy

Our thematic content analysis reveals two dimensions of entropy that can be spontaneously identified by participants when talking about their packaging: 1) statistical entropy and 2) the link between entropy and energy quality and system stability. Table 2 defines these two dimensions as they apply to packaging.

Statistical entropy comes from the multitude of states that the particles in the system can take on (their microstates), and therefore reflects the diversity of visible or felt characteristics of a packaging over the course of its use. Consumers assess these microstates through three types of observable cues-: colour, shape and texture cues. Firstly, stains are used as cues to evaluate the packaging, as Christelle said about tomato sauce stains: ' *Oh yeah... even with tomato sauce... on glass it doesn't stain... on plastic it stains...*'. Secondly, Bilal described a metal container in the following way: ' *Metal in itself can be a bit pockmarked* '. *The* more possible microstates consumers perceive, the higher the perceived level of statistical entropy: the judgement of the macrostate of the packaging as a whole is therefore more 'entropic'. Our analysis by material (see Table 3) shows that wood has the highest level of entropy linked to the diversity of its microstates. As far as the macro-states of packaging are concerned (their overall state), consumers rely on their perception, such as the solidity of the packaging: ' *Yes, I think it's solid...*' and ' *Well, for me, this one would last longer... longer, more solid* ' say Karine and Magalie respectively for their metal packaging. Once again, our analysis by material shows that wood has the highest level of macro-state entropy.

4.2 Perception of exergy and system stability

Perception of exergy: Glass is appreciated for its hermeticity and its capacity for conservation: ' *You have to admit that glass is the best for conservation* ', Serge. It is perceived as having a high exergy but a loss of these properties often leads to its rejection: ' *Glass can either be used or broken* ', Chloé. Metalis recognised for its high storage capacity and durability: ' *Steel [...] is pretty solid and stores well* ', Bilal. Its low entropy, combined with high exergy, explains why it is frequently reused: ' *In iron cans, it keeps for a very, very long time* ', Jocelyne. Wood, on the other hand,is perceived as not preserving food well: ' *It's not the best preserver* ', Dominique. Plastic is also perceived as having a poor preservation capacity and therefore low exergy: 'I must admit that plastic foodstuffs are really transient', Dominique, talking about her plastic tins. In the end, metal and glass are the materials with the best exergy (61% and 57%).

Stability of the system: Glass, according to the participants and unlike plastic, seems to be a healthy material, meaning that glass is highly stable, while plastic is less stable: '*I don't think that glass, with the temperature of a microwave, is likely to contain micro-particles of glass, unlike plastic* ', Bilal. What's more, plastic becomes porous: 'Well, I figure that plastic things always end up a bit porous...', Rose-Marie. Wood isn't stable, because it's easily affected by its environment: '*For me, wood is a living material that absorbs what's going on outside*', Delphine, and it pollutes its contents: '*I think it would make food taste bad. And I'm not a fan*...', Magalie. As for metal, the environment seems to have little impact on it: '*You see, once it's been cleaned, it doesn't move once I've cleaned it* ', Magalie, referring to a metal tin. So wood and plastic seem to be the two least stable materials for the participants (see table 3).

In physics, high entropy corresponds to low exergy, reducing the system's ability to fulfil its primary function. In the case of plastic, this low exergy does not rule out non-food reuse, underlining its versatility. On the other hand, for glass, whose exergy is based mainly on its hermeticity, the loss of this function generally leads to its rejection. Metal, thanks to its high energy content and preservation capabilities, remains a reliable and frequently re-used material. Finally, although wood has limited exergy, it is used for secondary purposes. So, the perception of entropy, combined with the evaluation of exergy, guides consumer choices. These decisions, influenced by the specific properties of the materials, highlight the importance of sustainable packaging design**.**

5. Discussion

5.1 Theoretical Contributions

This research adds to the literature on materials by introducing the concept of perceived entropy into the assessment of packaging condition. It highlights how consumers interpret wear and tear and physical cues (microstates) to form an idea of the overall condition of the packaging (macrostates). Depending on the packaging material, respondents use different indicators. By linking perceived energy quality (exergy) and system stability (hermeticity, contamination), it clarifies the criteria influencing consumers' perceptions of their packaging.

5.2 Managerial Implications

This research offers concrete avenues for improving the design of reusable packaging. The results highlight the importance of the choice of materials in packaging design, as the material influences the way consumers judge the condition of the packaging. Managers can use these perceptions to develop packaging that minimises signs of wear and tear (stains, odours) and maximises shelf life and hermeticity. Limiting our approach to packaging may seem reductive in relation to the product, but it is justified: attractive packaging can boost sales by adding perceived value and, if it is reusable, makes a positive contribution to the environment.

5.3 Limitations and Future Research

This study has certain limitations. Firstly, it does not consider variations in quality within the same material (e.g. plastics of different strengths), although participants spontaneously mentioned this aspect. Secondly, the sample included a majority of women, which could limit the generalisability of the results to other populations. Further research could explore the impact of perceived entropy on the desire to reuse, include analyses of multi-material packaging, and examine the influence of labels (e.g. 'reusable') on the perceived value of packaging.

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