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Investigating openability of rigid plastic containers with peelable lids: The link between human strength and grip and opening forces

Laura A Canty[1], Roger Lewis[1] and Alaster Yoxall[2]

Abstract

As society ages there is a growing need to understand issues surrounding declining user capabilities. One such area has been accessibility of packaging by older people. To date much of the current research in this area has focused on measuring strength of older people and analysing the force needed to open various pack formats and has largely concentrated on accessibility of jam or sauce jars. However, a survey by 'Yours' magazine indicated that problems with thin film pack forms and peelable packaging was also an issue for older people. Hence the authors undertook a small-scale study to understand the issues surrounding accessing a rigid plastic container with a peelable lid. To that end the authors built a bespoke measuring device to measure container peeling forces, measured finger friction between pack and finger and undertook an observational analysis on 60 users accessing packaging of this type. Results indicated that the force needed to open containers of this type is lower than measured user forces including older people and it is therefore likely that the issues surrounding accessibility of this type of pack format are related to dexterity not strength. However, the authors also showed that this can be affected by context of use in that oily fingers could reduce the friction coefficient between finger and pack such that older people may not have sufficient strength to open packs of this type.

Keywords

Packaging, openability, inclusive design

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Introduction

In 2009, the UK market for plastic packaging was worth an estimated £3.47bn, between 2005 and 2008, the UK market value grew by 15.6%. Further, more than 1.65 million tonnes of plastic packaging are consumed in the UK every year, equivalent to just over 27 kg per capita. If present trends continue, plastic is expected to become the packaging market's largest sector at some point within the next decade, overtaking paper and board. Packaging is the leading application for the UK plastics industry, currently accounting for 38% of annual usage. Leading end-user industries for plastic packaging include food and drink, pharmaceuticals, and cosmetics and personal care.[1]

Plastic packaging is usually found in two forms, termed rigid plastic (such as milk bottles or beverage bottles and pots) or flexible plastic (such as shrink wraps and pouches).[2] Designers have to balance two conflicting requirements with this type of packaging; the need to prevent the packaging opening prematurely or by accident and the need to allow easy access when the packaging is being opened intentionally.[3]

However, the ease of access to a pack is becoming a major concern for the packaging industry. Society is ageing, in 1950 there were approximately 200 million older adults (defined by the US Census Bureau as +65) rising to 487 million in 2006 and predicting to rise to 1.55 billion by 2050.[4] In the UK, the population is projected to become older gradually, the average (median) age rising from 39.3 years in 2008 to 42.2 years by 2033. However, the numbers of people at the oldest ages is increasing rapidly. The number of over

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85's is predicted to more than double between 2008 and 2033 rising to some 3.3 million.[5]

This demographic shift creates a major public health problem; that with increasing age there is an increased risk of development of a number of age-related pathologies. With ageing, there is loss of strength and dexterity, decline in cognitive function, impaired immune function, increased susceptibility to infection and increased risk of heart disease and cancer.[6–8] Hence with the associated decline in strength dexterity and cognition, a larger proportion of society will in future potentially experience problems of accessibility to everyday items such as food or healthcare products.

Indeed, a 2004 survey by McConnell for the magazine 'Yours'.[9] Over 2000 people were questioned about their difficulty in accessing packaged goods with bleach bottles and jars ranked first and second in their perceived difficulty by aged consumers.

Given that jars ranked so highly in the survey it is of no surprise that the bulk of previous work in this area has looked at strength issues in relation packaging of this type.[10–13] The authors have also recently looked at issues surrounding accessibility of bleach bottles.[14]

Less work has been undertaken, however, on accessibility of packaging items requiring the peeling of a film or lid although these packaging types rank highly as problematic packaging in this survey. Further, no work has been undertaken to understand whether the accessibility of products of this type is one of strength or dexterity or indeed a combination.

Therefore, in order to understand the problem more clearly, this investigation focussed on three interlinked areas of peelable rigid plastic packaging and used yogurt pots (as shown in Figure 1) as a case study example (Figure 2):

- The required opening force (linked to the strength of the lid seal) – there needs to be a compromise between the seal strength and the ease of opening.
- The technique used to open the lid – this includes the way people grip the tab on the lid, the way they hold the pot and the angle they pull the lid off at.
- The force people can apply to pull the lid off with – if the strength needed to pull the lid off is greater than the strength people can exert, then the pot is unusable.

Yogurt pots were chosen as they were typical of thin-film lidded rigid plastic containers of this type and the authors were supported by a UK producer willing to supply lids and containers sealed at varying temperatures. The lids themselves were polypropylene although aluminium and polyester variants are produced depending on the application. An example of this type of packaging is shown in Figure 1.

Figure 1. Typical rigid PET container with flexible peelable lid. PET: polyethylene terephthalate.

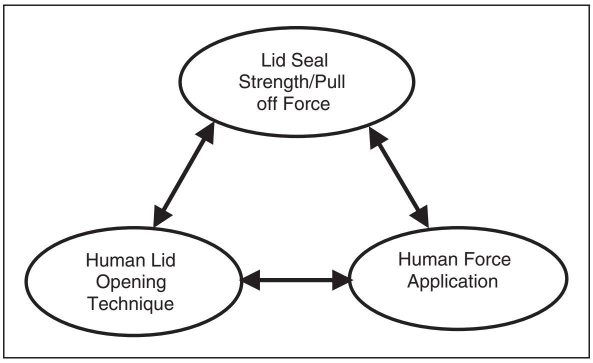

Figure 2. The three areas of research into flexible packaging.

There were several aims of this work, firstly to pull the three areas of research together to form a design methodology for improving the openability of peelable packaging of this type packaging. This 'three-stranded approach' to understanding the relationship of human ability to pack function has been outlined previously,[16] but this is the first time it has been put into practice on an actual piece of packaging. The secondary aim was to understand whether issues surrounding this pack were related to strength, dexterity or a combination of the two.

This approach could certainly be rolled out to any type of packaging, and while yoghurt pots may have turned out to not be a significant problem when compared to other forms of packaging, they are a good starting point from which to understand the issues and trial the proposed methodology.

Work was carried out initially observing participants pot opening techniques, in particular the grip style used and any spillage and comments made by

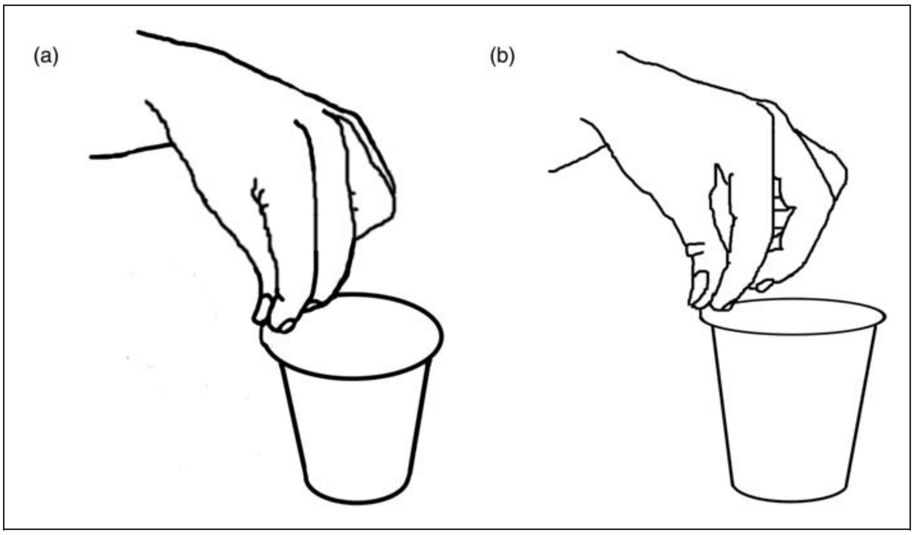

Figure 3. (a) The pulp pinch pull (PPP) grip; (b) the chuck pinch pull (CPP) grip.

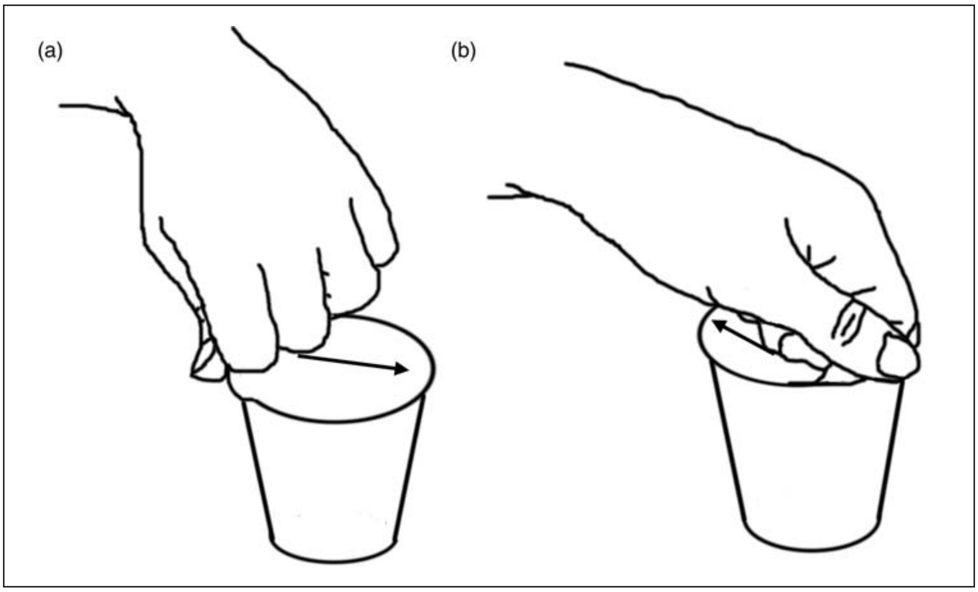

Figure 4. The lateral pinch pull (LPP) being used to open a lid away from the user.

the participant. Measurements were taken using a bespoke test rig to obtain pot opening forces. Finger friction measurements were also carried out to look at how easy the lid material is to grip under a number of conditions. This data was compared with opening forces to determine whether fingers would slip before opening was achieved.

Background

Gripping techniques and forces

The Department of Trade and Industry (DTI) in the UK have developed techniques for testing human grip.[17] The data describes generic functions rather than being product specific so that it can be used in as many design applications as possible. The most relevant to this study is pinch-pull strength.

The test to measure this strength uses one hand (usually the dominant one) at three pinch distances. Two grip types are tested; the pulp pinch pull (PPP) (pad of the thumb opposing the pad of the index finger) (see Figure 3(a) for illustration) and the chuck pinch pull (CPP) (the pad of the thumb opposing the pads of the index and middle fingers) (see Figure 3(b) for illustration). The lateral pinch pull (LPP) (the pad of the thumb in opposition to the side of the index finger with the rest of the fingers backing it up) (see Figure 4 for illustration), whilst observed in this study as a technique used was not included.

The test apparatus is made up of a strip of material (made from, for example, textured fabric) clamped into an instrumented box (as shown in Figure 5). Test subjects are asked grip and pull using the maximum force they can without causing injury to themselves. There are very definite rules about how the equipment should be used. These include standing in front of the measuring device, building up to a maximum strength in the first few seconds and maintaining the strength for a further few. Data gathered for a series of tests with 2-mm-thick material is shown in Figure 6. As can be seen the CPP allows a greater pulling force than the PPP and the force decreases with increasing age, as would be expected. Further tests with thicker test specimens showed that greater force could be applied if the gripping (pinch) distance was increased. This probably means that the forces at 2 mm are greater than would be expected for a thin film of material as commonly found on flexible packaging. This test, while providing an important insight to pulling forces is a bit too generic to be applied to flexible packaging. When grip is used in everyday activities (to open packaging for example) there is no set rule about which gripping technique to use and so a more realistic way of measuring grip is needed.

Another piece of work carried out by the DTI was more specific, focussing on peel-back forces.[18] A preliminary study was used to investigate which types of packaging were the most difficult to open. This involved two focus groups which were sat around a table with a video camera mounted at one end. Members of the groups were asked to open a type of packaging while the other three observed. They were encouraged to talk about their experiences with packaging at home. There was a knife and a pair of scissors in the centre of the table. It was found that factors that caused the most problems were small and slippery grip areas and packages that were sealed too strongly.

An instrument was developed during the study for measuring peel back strength. The size and weight of the peel-back tester was determined by the instrumentation built into it. This meant that the tester was not representative of a specific piece of packaging. The participants were asked to peel back one of the tabs or pull the tabs apart from each other in a variety of different ways and the results were recorded. Different tab sizes and shapes were tested in the rig. Tests were carried out on groups of able bodied and disabled test subjects.

The results, shown in Figure 7, are for the test unit with one tab, placed on the worktop. One hand was used to stabilise the unit and the other grasped the tab (20 mm long) and exerting a peel-back pull with the wrist rotating. It is not clear which grip method was used on the tab or even if this was noted. The data could be used, however, to determine a threshold force required to open a piece of packaging. Ideally this would be achievable by 100% of both able bodied and disabled users.

Work by Imrhan[19] recognised that pinching and pulling are extremely important functions of the hand. It was found that the type of grip used for a pulling task is mainly influenced by the shape and surface area of the object available to the fingers for

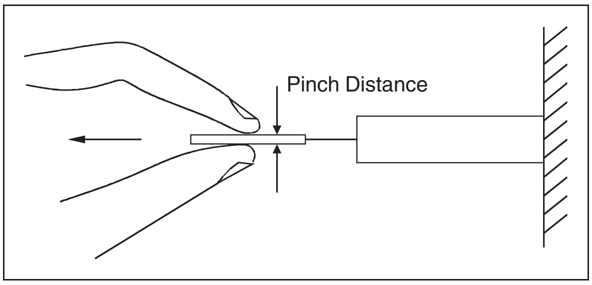

Figure 5. Pinch-pull force measurement apparatus[17].

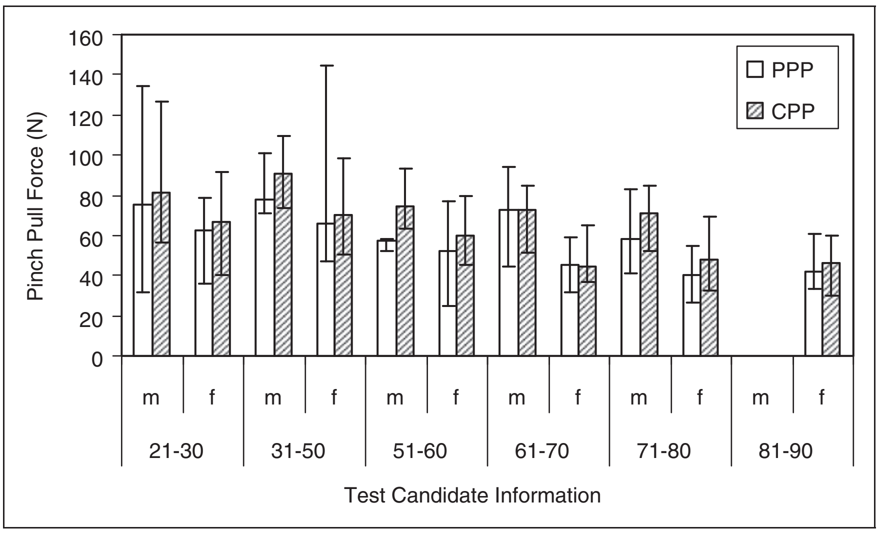

Figure 6. DTI pinch-pull force data for a 2-mm-thick material (replotted from Peebles and Norris[17]). DTI: The Department of Trade and Industry.

pinching and the task to be performed. If a small area is available to the subject, a PPP technique will be used, but if the area available is larger, a CPP or LPP will be used. The most powerful grip was found to be the LPP followed by the CPP and least powerful was the PPP. This was not found to change with pulling direction. Therefore, the work concluded that products should be designed to take advantage of the fact that larger purchase area allows for the stronger grip type to be used.

Peel force measurement

A number of test rigs are available commercially for measuring peeling forces. One example is the peel back force tester.[20] This piece of equipment is used to accurately record the peel back force readings for removing cover tape from carrier tape (used to protect components when they are being transported).

An instrument for testing yogurt containers is also available from Lloyds Instruments.[21] The TG 5346 peel fixture is an accessory that allows testing of the optimum peel strength of sealed lids on yogurt pots. It consists of an angled platform that is positioned on a base plate and locked securely in a position to suit the container being tested. When the lid is pulled off using this apparatus, the angle of peel is constantly changed.

There is no standard test for peel force and there are no standards relating to required opening forces for flexible packaging. However, many companies have their own set of 'requirements' with regard to opening force.

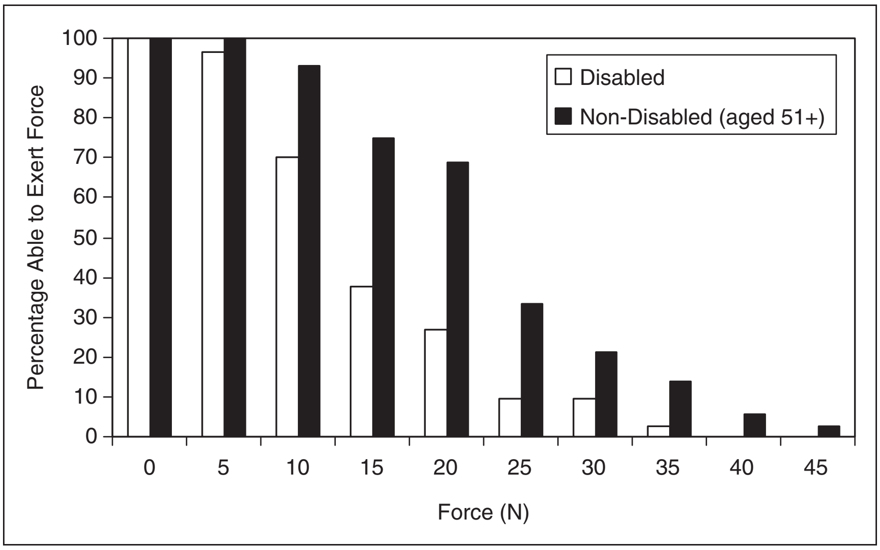

Figure 7. Peel-back pull strength with the wrist rotating with a single 20 mm tab.[18]

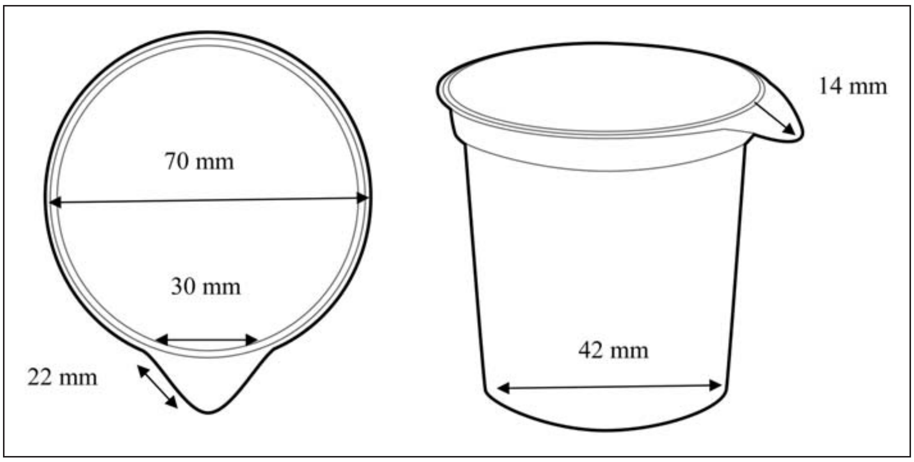

Figure 8. Dimensions of yogurt pots used in opening study.

Summary of previous work

The investigation of previous work and methods that could be used led to the decisions to initially investigate opening techniques using an observational approach, i.e. giving people pots and seeing how they interacted with it and eventually opened the lid to see where the problems were. This has been used successfully in other studies by the authors.[22]

Although there are clearly machines available for measuring opening forces, it was not clear that they exactly mimicked the opening behaviour. From the observational studies it was intended to use high speed video techniques to assess opening speed and angle to build this into a new test for opening actual pots that gave greater flexibility. Finally it was decided to analyse the finger pad interaction with the lid material to a greater extent that has been done before, in terms of friction, and to use this to predict human force capabilities by combining the output with pinch force data already available.

Human lid opening technique

The technique people use to open flexible packaging varies. This can be due to what ever feels the most comfortable, which may be affected by a disability or lack of mobility, or because certain grips give different levels of strength in different circumstances. To establish how yogurt pots are opened a simple ethnographic study was carried out.

Approach

Video techniques questionnaires and photographs to analyse the techniques used in opening yogurt pots. Sixty studies were undertaken across a wide age range. Participants were drawn from staff and students at The University of Sheffield and Sheffield Hallam University on a voluntary basis. Test participants were in a seated position at a table when they were given the pots to open. They were videoed from a distance to ensure that they were not affected by the camera being too close.

The main questions that were asked about the interaction people had with the yogurt pots were:

- How did they hold the pot?
- How did they locate the tab and how was it gripped?
- What direction was load applied in (toward them or away)?
- Were any problems encountered while trying to open the pot?

Specimens

The yogurts used in the study comprised of plastic pots (polyethylene terephthalate (PET)) with plastic lids (polypropylene (PP)). A diagram of a pot can be seen in Figure 8. The lids, in order to use the minimum amount of material, are cut from squares that have a side length the same as the diameter of the pot at the top. This means that for this pot the tab was 14 mm long.

Results

It was found that there were three common types of grip that people chose when they opened the yogurt pots. These were the grips described earlier; CPP, PPP and LPP, and are illustrated in Figures 4 and 5. Whilst there is no official definition of what age a user becomes an 'older adult' here it has been taken as 60 years (consistent with the World Health Organization and the United Nations[23]). Table 1 shows the age and observed grip for male and female participants. The data is split between those over or under 60 for both genders. Figure 9 shows how many pulled towards or away.

The most popular grip by far was the CCP, mainly pulling away from the body. This type of grip obviously generated enough force to open the pot. This grip would be easy to use for people with poor dexterity because it does not involve the fingers bending to the extent they would have to if a LPP grip was chosen. The LPP was the second most popular. While it generates the most power, it requires a relatively large area for pinching which clearly yogurt pot lids, and many other forms of flexible packaging, do not offer. It is noticeable from Table 1 that more 'younger' test participants opted for the LPP grip, which may have been because of their greater dexterity. The least popular grip was the PPP. This type of grip generates the least power[19] and so this is probably why it was not an obvious choice. No obvious differences emerge between female and male test participants.

Table 1. Grip type for male and female test candidates.

	Grip type		
Age band	CPP	PPP	LPP
(a) Male			
60<	6	2	7
<60	4	3	2
(b) Female			
60<	7	1	7
<60	7	4	10

CPP: chuck pinch pull; PPP: pulp pinch pull; LPP: lateral pinch pull.

In terms of whether participants pulled the tab towards them or away some significant differences are clear. Participants over 60 were far more likely to pull away from themselves, i.e. they did not want, perhaps, to go through the procedure of re-orientating the pot so the tab was on the far side of the pot. This is interesting as it is this orientation that is more likely to lead to yogurt 'spraying' onto the candidate (Figure 10). It may be another issue created by lower dexterity.

Problems opening/handling the pots were also recorded if they occurred. The details are shown in Figure 11, again with a split between under 60 and over 60. It is possible to see from Figure 12 that a reasonable number of test participants had problems with opening the lids. Most (for younger and older participants) were related to locating and lifting the tab, an issue directly related to dexterity and relative finger pad/tab size. The older participants also had problems opening the lid completely or with both in combination, which were not an issue for the younger users. Incomplete opening may be a strength issue or could be associated with a problem with wrist twisting to continue the pulling motion to the far side of the pot.

High speed recordings of yogurt pot opening were taken to establish opening angles and speed for the testing to be carried out to measure opening forces. The results showed that force was applied at an angle of approximately 30° and the opening speed was of the order of 500–600 mm/min. This was used in developing the test method for assessing lid pull off force required (outlined in the next section).

Lid pull-off force

An understanding of how difficult the lids are to peel-off is important. This can then be related to the strength people can exert when pulling a lid off. In order to measure the force required to pull the lid off, a machine was needed that could pull in a uniform, repeatable manner. Standard approaches did

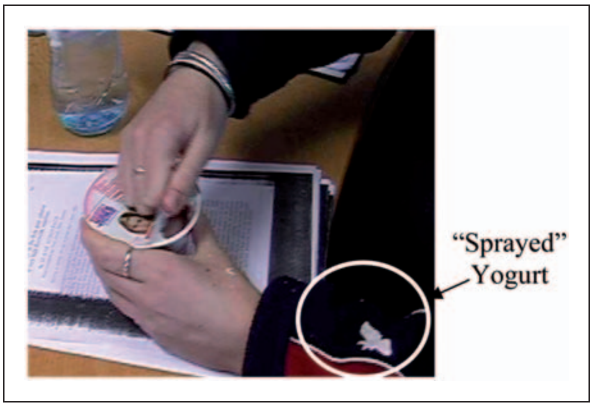

Figure 10. Typical yogurt spillage during pot opening (using an LPP grip).
LPP: lateral pinch pull.

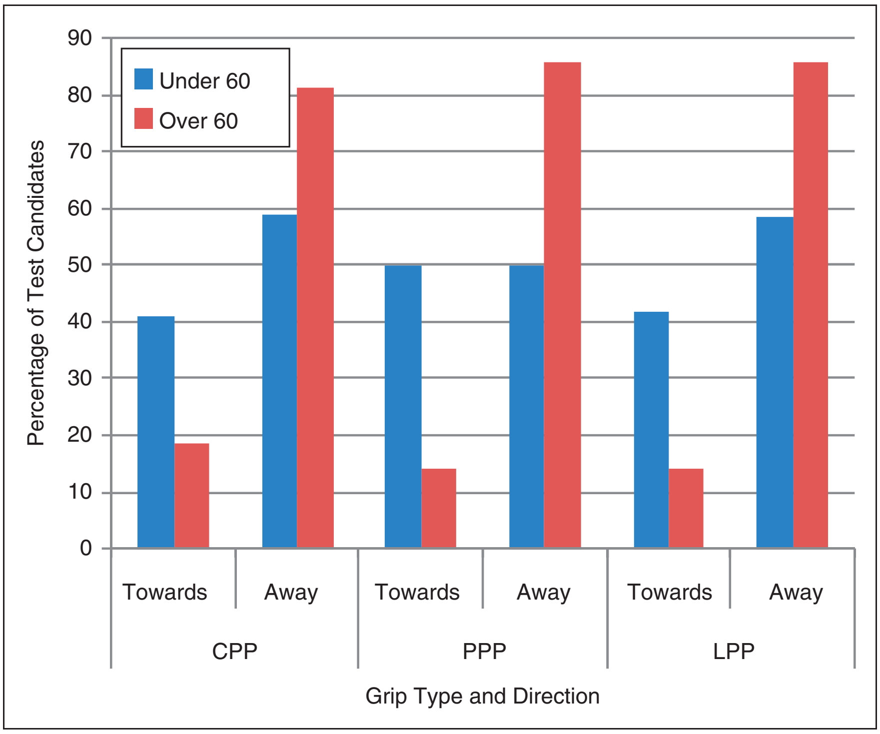

Figure 9. Proportion of test participants peeling towards and away from themselves.

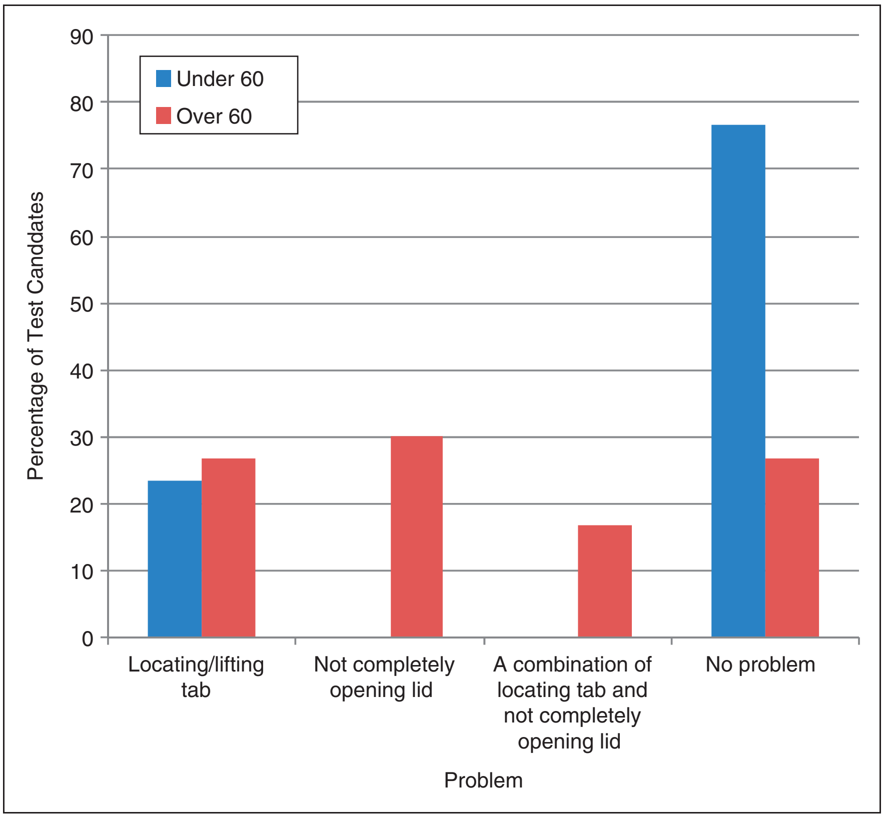

Figure 11. Problems with lid opening.

not give any flexibility so a new method was devised based on standard servo-hydraulic test apparatus.

Apparatus

The peel strength of the pots was found by using a bespoke rig mounted in a hydraulic test machine. The rig (shown in Figure 12) was designed to be bolted onto the test machine. A specially designed clip on a cable fixed to the top of the test machine was attached to the tab (Figure 13). The pot was held on the rig by hand as it was moved down by the test machine (in displacement control). As this happened the cable tightened and moved around the roller and the tab was pulled back and the lid was peeled off the pod when the opening force was achieved. While being used for yogurt pots in this study the rig was kept relatively simple in order to allow testing of other flexible packaging.

The rig has a number of advantages over commercially available test apparatus, which include the ability to maintain the opening angle during lid pull-off, variable pulling speed and the fact that a variety of packaging types can be tested.

The hydraulic test machine was set to move down at a constant velocity of 600 mm/min. This speed was chosen to represent the way pots are opened in every day life (as measured during the observations). A separate load cell was incorporated into the hydraulic test machine as the built in cell had too high a range for this application (forces down to 0.1 N could be measured). Force data was logged during tests.

Pots sealed at five different temperatures were tested (180 °C to 220 °C at intervals of 10 °C). Ten pots sealed at each temperature were tested. Sealing temperature is usually optimised to give the seal quality required while still allowing the pot to be opened easily. There is, however, no standard for opening forces in relation to flexible packaging. The pots used were manufactured from PET and had PP lids and did not have yogurt in.

Results

The results generated from the testing were displayed as plots of force against time. An example of a result for a pot sealed at 200 °C can be seen in Figure 14.

The force builds up to a peak which occurs when the seal is broken and the lid starts to peel off. The force then immediately drops off to a range it stays at for the rest of the duration of the peel. The fluctuation in the force for the rest of the peel occurs because one side of the lid opens slightly, then the other side repeatedly.

The average opening forces measured along with the spread observed is shown in Figure 15. A steady increase can be observed as the temperature is increased. This result was expected as a higher temperature leads to a stronger seal. However, the amount of spread of maximum force, in particular

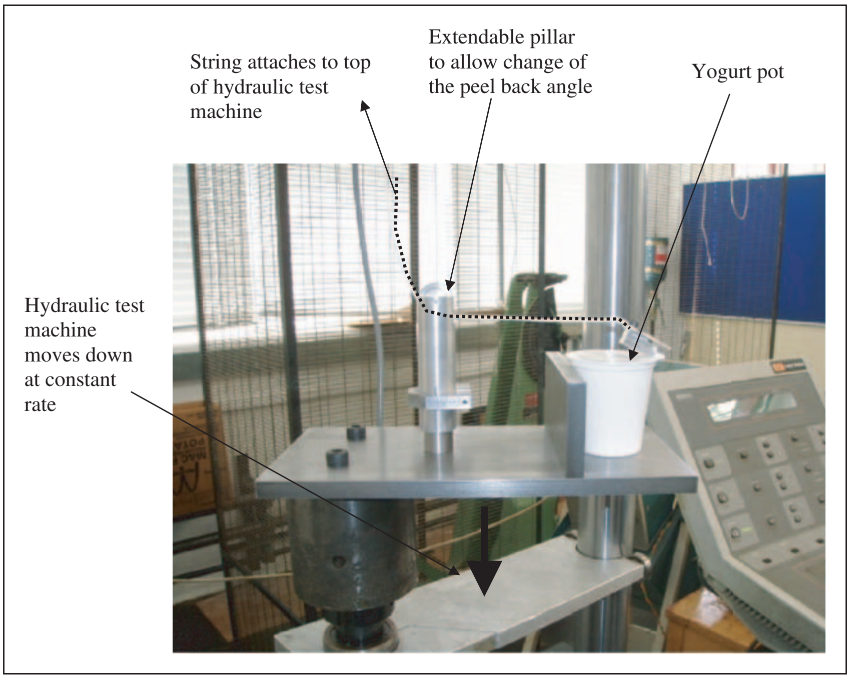

Figure 12. Lid peel test apparatus.

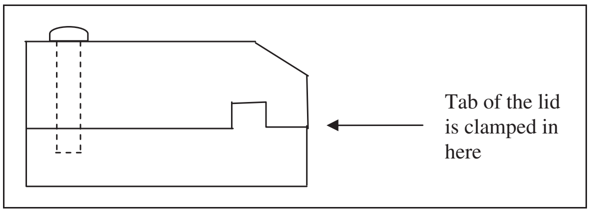

Figure 13. Clip used to attach to the tab on the lid to the hydraulic test machine.

for the pots sealed at 190 °C, 210 °C and at 220 °C, was unexpectedly high. Studies carried out on the seals using ultrasound[24] have shown, however, that large variation in the quality of seals (even those at nominally the same temperature) occurs, which could explain the spread.

Comparison with human pinch-pull data

Comparison of the opening forces measured with the DTI data for 'pinch-pull' (Figure 6) and 'peel' strengths (Figure 7) indicates that most people will be able to open yogurt pots. Some disabled users, though, may find it more difficult. Of course, however, this strength data is for the wrong type and thickness of material and the measurement process did not require any kind of manipulation as opening real packaging would. The strength data is therefore really an upper boundary. Measurement techniques for human strength are required that involve more realistic scenarios.

Finger friction measurements

To further understanding of hand/pack interaction an indication of how easy the pack is to grip is required. Finger friction measurements were taken on yogurt pot lid material (PP) and used to work out at what force the fingers would slip. This data was then compared with opening force data. While here it could clearly be anticipated that the slip force would be higher than that of the opening force, with other packaging this may not be the case. This exercise was really performed to establish the measurement technique and is included here to provide indicative information. The methodology of using a single subject to produce indicative results was previously used by the authors to study finger to pack interaction on a range of bottle/closure materials.[25]

Apparatus

The rig used in the testing is shown in Figure 16. It basically incorporates two load cells and a block to hold the counterface material. The load cells were carefully selected to be able to take account of effects due to eccentric loading. This was because as the finger slides on the counterface the position relative to the normal force load cell will change. Voltage measurements from the load cells were downloaded, via two strain gauges and an oscilloscope, to a PC, where they were converted to force values using the load cell voltage/force relationships and finally to friction coefficients. Before use, both load cells were calibrated by applying dead weight loading and recording

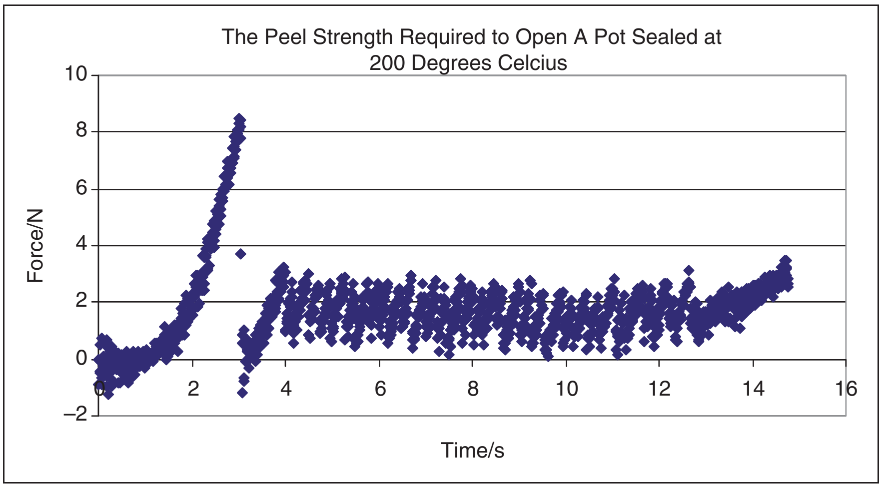

Figure 14. Force against time for a typical pot opening experiment.

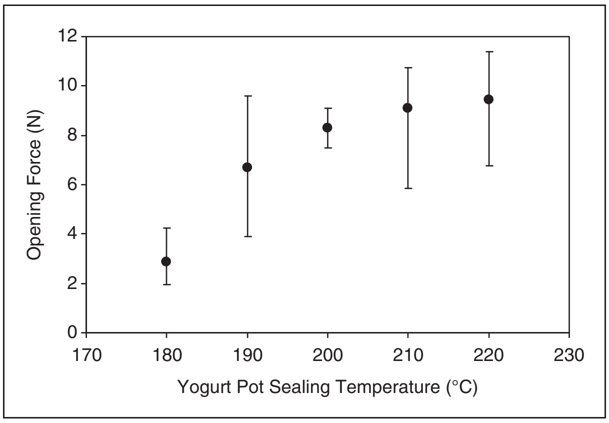

Figure 15. Maximum peel force recorded at five sealing temperatures.

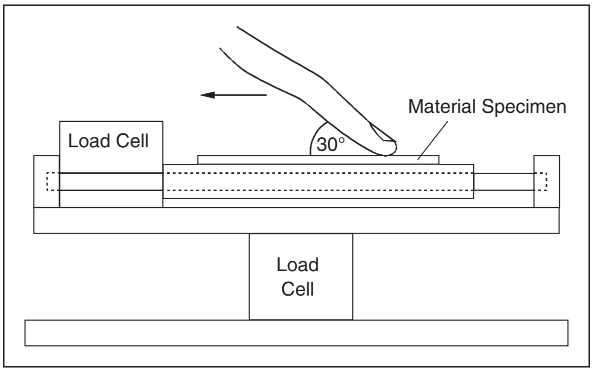

Figure 16. Schematic of finger friction measurement rig.

the output voltage to obtain the voltage/force relationships required for the data analysis.

As mentioned previously the rig has been used in an earlier study to analyse finger interaction with a range of bottle/closure materials.[25] The rig was validated by sliding various materials along a steel counterface.

Test methodology

The index finger (of a 23-year-old female) was set in position at an angle of 30° to the counterface with the yogurt pot lid attached and the tip was placed on the counterface (Figure 16). The user then adjusted the load applied to be around 20 N. This was used as it was found that good control could be exerted at this level of load. Tests were carried out in dry, slightly wet and oily conditions. In each test one drop of liquid were applied to the test surface at the finger application point.

In performing the tests, once the finger was adjusted and the load was at the required value, the user attempted to slide their finger, as slowly as possible, along the counterface. This was because when gripping something the finger is not actually meant to move. This technique proved successful, as a clear static coefficient of friction could be identified in the results. Once movement did occur the finger motion was continued down the counterface. Tests were repeated ten times for each set of conditions. Fingers and counterfaces were cleaned and dried thoroughly between tests.

Figure 17 shows the friction coefficient values determined by dividing the friction force by the normal force. The important data was the static value, which is indicated.

Results

Static friction results are shown in Figure 18. As can be seen, slightly wetting the surface actually increases friction. This has been seen before[26–28] and is analogous to 'licking' a finger when opening a plastic

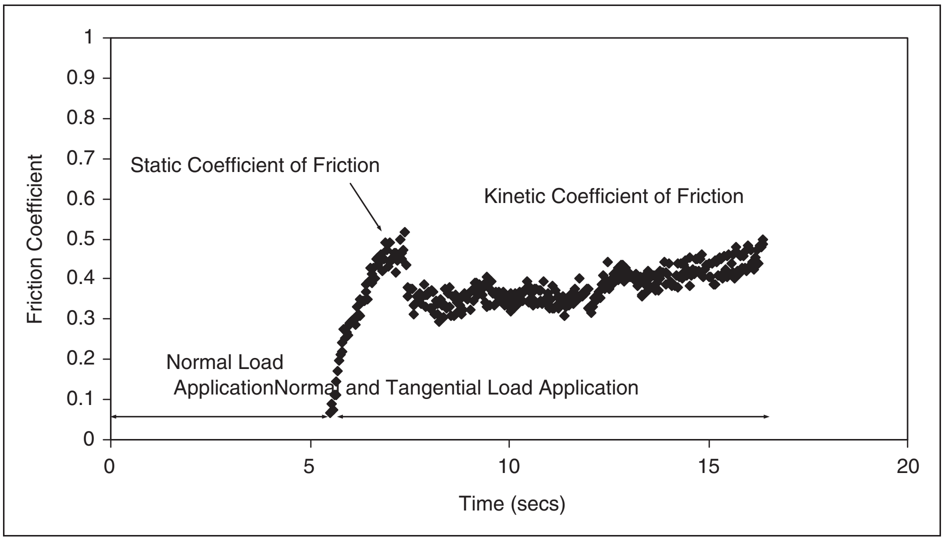

Figure 17. Friction coefficient against time.

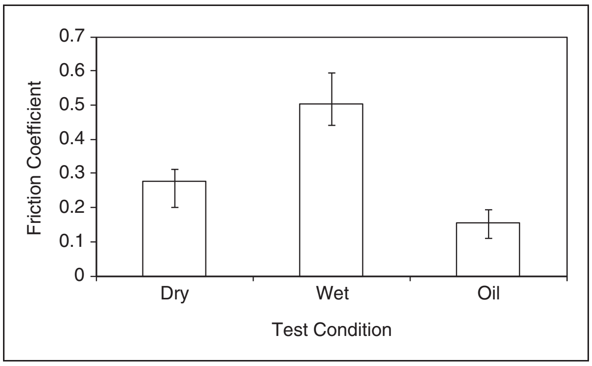

Figure 18. Static coefficient of friction values for the conditions tested.

Table 2. DTI force data for index fingers[18].

Age	Gender	Index finger Min	Avg	Max
21–30	M	76	118.67	155.6
	F	55.9	78.87	98.4
31–50	M	85.6	122.17	174.2
	F	66.4	87.12	111.8
51–60	M	55.4	104.12	137.5
	F	53.8	67.62	79
61–70	M	73.5	101	121
	F	59	65.78	73.2
71–80	M	58.6	83.52	103.3
	F	41.4	58.29	84.6

DTI: The Department of Trade and Industry.

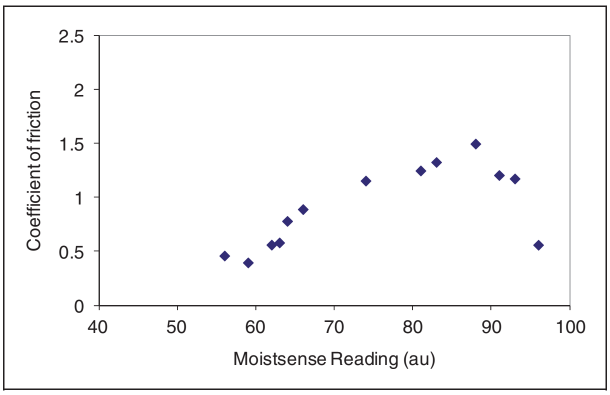

Figure 19. Variation of friction coefficients with moisture for tests run against PVC (taken from Tomlinson et al.[26]).
PVC: polyvinyl chloride.

carrier bag, for example. Figure 19 shows some sample data for a finger sliding against PVC for varying moisture levels (from Tomlinson et al.[26]).

Using finger 'press' forces measured by the DTI[29] (and shown in Table 2 for different ages) as the pinch/normal force, the friction coefficients can be used to calculate a slip force, F_s

$$F_s = 2\mu N \tag{1}$$

where, N is the finger press force and μ is the friction coefficient. The slip forces for dry and oily conditions are shown in Figure 20 for different ages and sexes. As can be seen, the forces are mainly well above the opening forces measured (Figure 15) so it should be possible for most users to open the pots even with oil on the tab. With oil though, more elderly female users

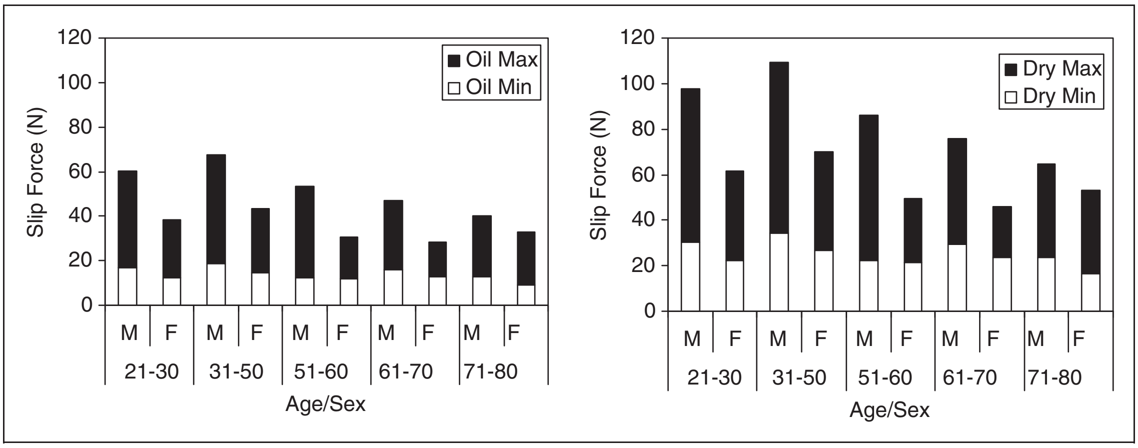

Figure 20. 'Slip' forces for the yogurt pot lids for oily and dry conditions.

may have problems as the minimum forces come close to the forces measured for pot opening.

Conclusions

Three areas of work have been carried out to investigate openability of a piece of thin film peelable packaging:

1. Participant observation has been used to establish problems with opening the packaging, opening techniques used and opening parameters, such as pulling speed, direction of pulling etc.
2. Opening force measurements have been carried out simulating the techniques observed during the observations and using the opening parameters determined.
3. Finger friction measurements have been taken to further understanding of the hand/pack interaction.

A significant amount of work has been undertaken assessing the strength needed to access jars and bottles.[30,31] However, less work has been undertaken assessing the use of flexible packaging by older people.

This work demonstrates that for flexible packaging of this type, dexterity is more of an issue than strength. Both force measurements and frictional data suggest that the opening event is within the capabilities of a large proportion of the population whilst the observation results showed older people having some difficulty manipulating the pot and the tab and hence use a grip choice that maximised the ease of opening. Given that a survey undertaken in a popular magazine aimed at older people[9] stated that shrink wrapped products, cellophane ready meals, milk and juice cartons and biscuits were problematic indicates that products where dexterity is an issue for opening rank along with those that require purely strength.

Like strength, dexterity is seen to decrease with age[32] and hence, improving accessibility of packaging of this type should concentrate on tab shape and design so that less dextrous fingers can locate and manipulate the tab.

The method used in this work can easily be applied to flexible packaging with more openability issues and the finger friction testing in particular used to develop material textures with greater friction to aid in opening this type of packaging.

However, whilst the work did show that for pack types like this it is likely that dexterity is more of an issue than strength, the authors also showed that context of use is important when understanding this issue. Packaging is often used in the kitchen or bathroom and therefore users will often have wet or oily hands. That oil on the hands say, may change the accessibility problem from one of dexterity to strength for older female users is an important insight for researchers and designers attempting to measure users ability and design more inclusive packaging.

Future work

To date, most research into packaging access has concentrated on issues surrounding strength and understanding issues related to declining strength in older people. However results indicate that declining dexterity is likely to be a significant issue when accessing packaging of this type. It is apparent that more work should be done to understand this issue in general. The authors seek to undertake a number off future studies in this area:

- understanding current 'state of the art' with respect to dexterity and packaging access in more detail.
- determine what features of pack formats affect packaging access.
- determine what user characteristics (age, gender, hand size) affect packaging access.

- undertake more detailed studies measuring friction coefficient between users and packaging materials.
- understand context of use relating to packaging access.

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