Perception of low social pressure and lack of capacity reduces vaccination compliance – The case of lumpy skin disease

Michal Morgenstern1 | Jaap Sok2 | Eyal Klement1

1Koret School of Veterinary Medicine, Hebrew University of Jerusalem, Rehovot, Israel
2Business Economics, Wageningen University and Research (WUR), Wageningen, the Netherlands

Correspondence
Eyal Klement, Koret School of Veterinary Medicine, Hebrew University of Jerusalem, Rehovot 76100, Israel.
Email: eyal.klement@mail.huji.ac.il

Funding information
Israeli Dairy Board, Grant/Award Number: 705-0078; STEP-GTP

Abstract
Successful prevention of epidemics depends on implementation of control measures, including vaccine compliance and maintenance of high vaccination coverage for long periods. However, to the best of our knowledge, a study of the temporal dynamics of compliance in voluntary vaccination campaigns and of the factors which influence them was never published. In this study, we investigated the factors influencing the dynamics of vaccination compliance against lumpy skin disease (LSD) after the occurrence of LSD epidemics in Israel in 2012–2013 and 2019. From 2016 to 2019, we followed voluntary LSD annual vaccination among a cohort of 566 farmers and used questionnaires based on the theory of planned behaviour to investigate the incentives influencing vaccine compliance among 90 farmers. The results showed a reduction in vaccination against LSD from 61% in 2016 to 27% in 2019 and a very strong association between prior vaccination and vaccination compliance. The actual vaccination by farmers who stated a positive intention to vaccinate was 4.5 times higher than farmers who did not (p-value = .007). However, half of the highly intended farmers eventually did not vaccinate their herd. These farmers were significantly more concerned by manpower and vaccine price compared to their vaccinating counterparts, pointing to vaccination effort perceptions as a major factor influencing compliance. In addition, we found that farmers who answered the questionnaires before the LSD epidemic of 2019 perceived significantly less pressure to vaccinate imposed by veterinary organizations (private and governmental) than farmers answering them during or after the epidemic. We conclude that the veterinarian-associated social pressure is a major compliance-enhancing factor, influenced by the occurrence of an epidemic. Our findings suggest that the deterioration of vaccination compliance after an epidemic can be mitigated by maintenance of pressure to vaccinate by veterinarians. Manpower support and vaccine discounts may be advocated to promote vaccine compliance.

KEYWORDS
epidemic, lumpy skin disease, theory of planned behaviour, vaccination compliance, vaccination compliance dynamics, voluntary vaccination
1 | INTRODUCTION

Vaccination is considered one of the most important measures of preventing and controlling both human and animal diseases. The success of every vaccination campaign is based on the vaccine characteristics such as its efficacy and safety and on vaccination coverage and compliance, which depend on human behaviour. The social–psychological factors influencing vaccination compliance have been widely studied, both in human medicine (e.g. Brewer et al., 2017; Chapman & Coups, 1999; Ratnapradipa et al., 2017; Schmid et al., 2017; Wheelock et al., 2013) and animal medicine (e.g. Elbres et al., 2010; Eschle et al., 2020; Gehrig et al., 2019). However, to our knowledge, investigation of the change of vaccination compliance through time (compliance dynamics) and the factors influencing it was never published. Such information is of primary importance, first for policymakers who wish to decide if vaccination against a certain disease should be mandatory or voluntary. Second, these data are essential for planning better intervention programmes to prevent deterioration of vaccination compliance.

To provide this information, we investigated the dynamics of Israeli dairy farmers’ vaccination compliance against lumpy skin disease (LSD), a vector-borne viral disease. We chose LSD as it is considered one of the most significant diseases affecting cattle. LSD is caused by the lumpy skin disease virus (LSDV), a member of the Poxviridae family and the genus Capripoxvirus (Tuppurainen & Oura, 2012). The disease is mostly characterized by the occurrence of localized or generalized skin nodules. It is often accompanied by lethargy, reduced appetite, oedema, reduction in milk production and might even cause death (Tuppurainen & Oura, 2012). Until 2012, LSD was mainly limited to Africa with some sporadic incursions which caused epidemics in the Middle East. From 2012, the disease had spread to Israel, Turkey, Greece, Bulgaria and other Balkan countries, Armenia, Azerbaijan, Kazakhstan, Georgia, the Russian Federation, China, India, Bangladesh, Syria, Cambodia, Hong-Kong, Malaysia, Vietnam and Thailand (EFSA, 2017; EFSA et al., 2019; https://wahis.woah.org/#/events).

To date, most of the commercially available vaccines against LSD are live attenuated, based on a LSDV strain, sheeppox virus (SPPV) or goatpox virus (GTPV) (Tuppurainen et al., 2021). A commonly used vaccine is based on the attenuated Neethling LSDV strain. There is a strong evidence that the Neethling vaccine was effective at preventing disease in Israel in 2012 and in the Balkans during 2015–2017 (Bengera et al., 2015; Klement et al., 2020). But the vaccination strategy, determined by the policymakers, varied in Israel. Five LSD epidemics occurred in Israel. The largest occurred in 2012 and lasted until August 2013. Thereafter, compulsory vaccination was implemented by the Israeli Veterinary Services (IVS). In June 2016, the IVS changed its policy and vaccination against LSD became voluntary. In 2019, a new epidemic of LSD occurred in Israel. These events allowed us to explore the dynamics of voluntary vaccination compliance among Israeli farmers and their relation to the occurrence of LSD.

For this purpose, we followed the annual vaccination compliance between 2016 and 2019 among a cohort of 566 Israeli dairy farmers insured by ‘Hachaklait’ (a veterinary cooperation, owned by the farmers, which provides veterinary services to about 80% of the dairy farms in Israel). In addition, we investigated the demographic and social–psychological factors influencing vaccination compliance among 90 dairy farmers using predefined questionnaires based on the theory of planned behaviour (TPB), a reasoned action approach. Such theories of reasoned action and planned behaviour are widely used in the study of medical behaviours (Albarracín et al., 2001; McEachan et al., 2016; Sok et al., 2021), including the motivation to vaccinate (Jozkowski & Geshnizjani, 2016; Sok et al., 2015).

The TPB predicts that a given future behaviour is explained by the intention to perform it. The intention is directly explained by three main constructs: attitude (A) (the person's favourable or unfavourable evaluation of the behaviour), subjective norms (SN) (the social pressures a person perceives to perform or not the behaviour) and perceived behavioural control (PBC) (the perceived own capability to perform that behaviour) (Ajzen, 1985). Further on, Fishbein and Ajzen developed the conceptualization of the TPB’s predictors of intention and defined two distinguishable subdimensions to the existing unitary definition of attitude and perceived behavioural control. Attitude was divided to instrumental and experiential. The instrumental factor is the perceived ability of the behaviour to produce desirable or undesirable outcomes. The experiential factor is the perceived ability of the behaviour to be pleasant or unpleasant. The perceived behavioural control was divided to capacity and autonomy. Capacity reflects the perceived capability of performing a given behaviour, and autonomy reflects the degree to which people believe that the performance of the behaviour is up to them. Regarding the subjective norms, a distinction between injunctive and descriptive aspects was made. Injunctive norms refer to people’s perceptions of what others would like them to do or what is expected of them. Descriptive norms refer to people's perceptions of what important others do.

The results of this study point to the major factors that influence both vaccination compliance and compliance deterioration. This reflects on the potential effectiveness of strategies to increase vaccination compliance.

2 | MATERIALS AND METHODS

2.1 | Study population and data collection

The study included two main datasets: (1) Vaccination and demographic data on 566 dairy farms insured by the ‘Hachaklait’ organization during the years 2016–2019 (Figure 1, Dataset 1). These data were collected from the ‘Hachaklait’ and included the type of herd (owned by family/cooperative/school), the district (which was classified into three geographic areas: north, centre and south) and payment for vaccination during the years 2016–2019. In addition, we collected information regarding the occurrence of an LSD epidemic in the herd during 2012–2013. (2) Ninety TPB questionnaires were filled out by dairy farmers regarding their intention to vaccinate against LSD (Figure 1, Dataset 2). These questionnaires were a subset of a larger survey performed among dairy farmers, inquiring about the intention to vaccinate against five cattle diseases. The questionnaires...
FIGURE 1  A graphic description of the study population. The study included two main datasets: (1) Vaccination and demographic data on 566 dairy farms insured by the Hachaklait organization during the years 2016–2019 (Dataset 1). (2) Ninety TPB questionnaires filled-in by dairy farmers regarding their intention to vaccinate against LSD (dataset 2). The intersection between these datasets yielded 56 questionnaires, for which we had data on voluntary vaccination (Data-intersect 1). These 56 questionnaire included 38 questionnaires filled-in by farmers who intended to vaccinate against LSD in the coming year. Half of these 38 farmers vaccinate their herds in 2019, while the other half did not. Dataset 2 was divided to 57 questionnaires which were filled-in before the 2019 epidemic and 33 after it were distributed at the annual Israeli cattle conference, which was held in December 2018, and in 13 following conferences, seminars, professional training courses and other meetings organized by the dairy farmers during the years 2019–2020. We intersected these two datasets to study the association of intention with actual vaccination. The intersection yielded 56 questionnaires. We could not intersect the remaining 34 questionnaires due to the lack of identifying details (Figure 1, Data-intersect 1).

2.2 The TPB questionnaire

The TPB is a theoretical framework but also comprises a set of guidelines to ensure proper measurement of the social–psychological constructs. A crucial step in applying the TPB is to define the behaviour in terms of its target, the action itself, the context in which it is performed and when it is performed (the TACT principle). Then, to conduct a pilot study in which readily accessible behavioural outcomes, normative referents and control factors regarding the behaviour are elicited (Francis et al., 2004; Sok et al., 2021). Our pilot study included semiqualitative interviews with 20 dairy farmers during October–November 2018 (of them, seven dairy farmers were asked about vaccination against LSD). This gave us a set of underlying beliefs for each of the constructs (A, SN and PBC). The interviews, as well as the questionnaire construction, were based on previous studies (Francis et al., 2004; Sok et al., 2015, 2016).

The questionnaire included three parts:

1. Questions measuring background factors. These factors were classified into farm and behavioural variables. The farm variables included questions on the type of the herd (family farm vs. single/double/triple cooperative farms), the herd’s yearly milk quota and the location of the herd. The behavioural variables included questions measuring perceived past experience and perceived risk as well as general questions regarding the gender, education and age of the farmer. Perceived risk was measured by the relative risk attitude and the risk perception. Risk perception was measured by multiplying two 7-point Likert-type scales, one with frequencies from ‘once in 100 years’ to ‘once in a week’ and one with the adjectives ‘No impact’ up to ‘High impact’. For measuring the relative risk attitude (with respect to animal diseases in general), each farmer was asked to compare his/her general risk perception to other farmers. This was performed by filling a 5-point Likert type scale that ranged from ‘absolutely disagree’ to ‘absolutely agree’, regarding four statements (Meuwissen et al., 2001). The TPB framework suggests that the background factors could explain variation in the intention. However, we examined whether these factors also have a direct effect on the intention.
2. Questions to obtain direct measures of the constructs of the TPB. A 5-point semantic differential scale with four different bipolar adjective pairs (e.g. unsatisfying and satisfying) was used to obtain direct measures of attitude. Injunctive subjective norm and PBC were measured with 5-point bipolar Likert-type scales with the endpoints 'disagree' to 'agree' (Sok et al., 2016). To prevent misinterpretation of questions regarding negative beliefs, two adjective pairs and one PBC statement were recoded so that higher numbers always reflect a positive attitude/self-efficacy/controllability to the target behaviour. Behavioural intention was measured by asking the farmer to scale his/her intention to vaccinate against LSD in the coming year between 1 (will certainly not vaccinate) to 5 (will certainly vaccinate). The survey only queried for measures of the injunctive norm.

Given the distinction between reflective and formative measurement, direct measures are required to show high internal consistency (see also Sok et al., 2021). We tested the internal consistency of the direct indicator for each construct by using the Cronbach's alpha scores. This analysis revealed a low internal consistency in the direct measures of the SN and PBC constructs (α = .6, .2, respectively) (Table S1). The indicator Nd3, which was based on the question 'I feel I have social pressure to vaccinate my herd against LSD in the coming year', had low within-construct correlations with the other two indicators (< 0.3) and was not correlated with the intention indicators (Table S1). This can be explained by the disagreement of the farmers with the firmer wording of this statement as compared to the other two statements. Regarding the PBC, all three indicators were not correlated with each other. However, as opposed to indicators Pd1 and Pd2, the indicator Pd3, which was representing the capacity dimension, did correlate with the intention (Table S1). In addition, although the internal consistency was appropriate for attitude (αC value of 0.8), only the indicators Ad1 and Ad2, which reflected experiential considerations ('necessary', 'contribute'), had high within-construct correlations and were correlated with intention (Table S1). Overall, to solve for the low internal inconsistency, we assessed only the indicators which were correlated with the intention (Ad1 and Ad2 for attitude, Nd1 and Nd2 for norms, Pd3 for PBC). We calculated the mean of these indicator scores to give an overall score for each construct.

3. Questions to obtain indirect (belief-based) measures of the three social–psychological constructs (A, SN and PBC). The most frequently mentioned responses from the qualitative part of the study were used to formulate behavioural, normative and control belief items. Consistent with the expectancy-value model, for each item, the belief strength is measured at a scale of 5-point Likert type that ranged from 'very unimportant' to 'very important'/not important' to 'very important'/more difficult' to 'more easy'. This time, the power of the control received a bipolar scaling and the motivation to comply a unipolar scaling. In the analysis, we changed the outcome evaluation scaling from bipolar to unipolar which was more logically fit (see Sok et al., 2021). Certain behavioural and control belief statements with expected negative influence on vaccination were recoded has been described for the direct measure. The resulting multiplicative products were analysed both individually and as an average.

The full questionnaire is attached to the supplementary materials.

2.3 | Data analysis

2.3.1 | Prediction of vaccination compliance against LSD in 2019 by previous vaccination

We examined the influence of the following factors on LSD vaccination in 2019 among 566 farmers: previous vaccination (divided into four categories: 1 No previous vaccination. 2 Vaccination only in 2017. 3. Vaccination only in 2018. 4. Vaccination in both 2017 and 2018), farm type (family vs. cooperative vs. school), geographic area (North, Centre and South of Israel) and previous occurrence of the disease in the herd (yes/no). Univariable analysis was performed by using the Chi-square test. Multivariable analysis was performed by fitting a logistic regression model to the 2019 vaccination data. Variables were included in the model in a forward stepwise process with a p-value of .05 in the univariable analysis as a cut-off for inclusion and a p-value > .05 in the multivariable analysis as a cut-off value for variable exclusion.

2.3.2 | Analysis of attitude, subjective norms and perceived behavioural control among farmers

We used the intersection data (Figure 1) for determining the association of the three constructs with actual vaccination among farmers who showed high intention to vaccinate. Thirty-eight of the 56 dairy farmers intended to vaccinate their herd (scores 4–5) (Figure 1). Vaccination records for the period preceding questionnaire filling were available for half of these 38 (future behaviour). For the other half, we had data on recent vaccination behaviour (up to 1 year prior to questionnaire filling). Within this group, we compared the three constructs’ direct and indirect measurements between those who did and did not vaccinate.

For determining the association of the three constructs with intention among the 90 farmers (Figure 1, Dataset 2), we compared A, N and PBC between farmers with negative and positive intention to vaccinate. We performed univariable analysis for each construct’s direct and indirect measurement using T tests. The intention was analysed as a dichotomic variable, scores 1–2–3 were marked as a negative intention and scores 4–5 as a positive intention. The same was performed for each belief. Similarly, we determined the direct effect of the
background variables (farm and behavioural) on the intention to
vaccinate. In that univariable analysis, we used Fisher/Chi-square tests.

2.3.3 | Effect of distance in time from LSD epidemic
on the intention to vaccinate and the three constructs’
direct and indirect measurements

Ideally, we would have distributed the questionnaires each year and
followed the change in these factors. However, the questionnaire study
began only in 2018, and data on vaccination intention in preceding
years were not available. In 2019, during the questionnaire study,
another LSD epidemic took place in Israel. This epidemic enabled us
to compare questionnaires filled in by farmers before the epidemic
and after the epidemic. Fifty-seven questionnaires were answered
before this epidemic while 33 questionnaires were answered during
and after its occurrence (Figure 1). These 33 questionnaires represent
a status resembling the situation after the epidemic of 2012–2013,
when vaccination became voluntary. The questionnaires which were
answered before the epidemic in 2019 (the ‘before’ group) repre-
sent the situation long after the epidemic in 2013 (Figure 2). The
comparison between the before and during/after the epidemic in
2019, therefore, represent different time distances from an LSD epi-
demic. Comparing the intention to vaccinate and the three constructs’
direct and indirect measurements between the two groups was per-
formed by using t tests after ensuring that the data were normally
distributed.

Intention to vaccinate was modelled using the data of 90 RAA ques-
tionnaires. A general linear model of intention to vaccinate was fitted
to the farmers’ beliefs, the location of the herd and the time from
the last epidemic (‘before’ or ‘after’) as the explanatory variables. The
model was fitted using a stepwise process with a p-value of .05 in the
multivariable analysis as a cut-off value for variable exclusion.

All statistical analysis was performed using R version 3.6.0 (R Core
Team, 2019), the ‘dplyr’, ‘itmit’, ‘Hmisc’, ‘olsr’ and ‘lme4’ packages (Bates
et al., 2015; Harrell et al., 2021; Hebbali, 2020; Rizopoulos, 2006;
Wickham et al., 2020).

3 | RESULTS

3.1 | Vaccination compliance

Between 2016 and 2019, we followed the annual vaccination com-
pliance among 566 cattle herd owners insured by ‘Hachaklait’ (the
veterinary cooperation providing private veterinary services to the
farmers). As depicted in Figure 3, we observed a reduction in vacci-
nation against LSD from 61% in 2016 to 27% in 2019. We also found
that farmers who withdrew from vaccination were less likely to vacci-
nate in the following years. Farmers who vaccinated their herds only
in 2017 were more than eight times more likely to vaccinate their herds
in 2019 as compared to the farmers who did not vaccinate their herds
in 2017 and 2018. The difference between farmers who did not vacci-
nate in both years to farmers who vaccinated in both years was even
more striking, where the latter was 120 times more likely to vaccinate
in 2019 (Table 1). A strong association was also found between vacci-
nation and the geographical location of the herd; farmers whose herd
was located in the centre of Israel were 20 times less likely, to vaccinate
than farmers whose herd was located in the north (Table 1).

FIGURE 2 | Outline of vaccination strategy and LSD epidemic in Israel between 2012 and 2021. Green – periods of voluntary vaccination. Red
– mandatory vaccination. The questionnaire study groups and the study rational are depicted by the rectangles in the bottom of the figure. The
‘after group’ represents questionnaires filled during and after the epidemic onset in 2019. The rational is that the ‘after group’ counterfactually
represents the situation immediately after ceasing mandatory vaccination in June 2016.

FIGURE 3 | The annual percentage of vaccination for lumpy skin
disease (LSD) among 566 Israeli dairy farmers during years
2016–2019. The blue line represents the percentage of policyholders
who vaccinated during January–December, except for 2019 (during
which vaccination became mandatory in June). The orange line
represents percentage of policy-holders who vaccinated only during
January–May in each year.
TABLE 1 The association between previous vaccination and geographic area to lumpy skin disease (LSD) vaccination in 2019

| Covariate          | OR (95% CI) for vaccination in 2019 | p     |
|--------------------|-------------------------------------|-------|
| Previous vaccination | None                               | Ref   | NA   |
|                    | Only in 2017                        | 8.39 (2.53; 32.46) | <0.001|
|                    | Only in 2018                        | 11.89 (1.15; 69.41) | 0.007 |
|                    | In 2017 and 2018                    | 119.54 (47.47; 403.43) | <0.001|
| Geographic area    | North                               | Ref   | NA   |
|                    | Center                              | 0.05 (0.01; 0.18)  | <0.001|
|                    | South                               | 0.63 (0.35; 1.08)  | 0.1   |

Note: A multivariable logistic regression on 566 ‘Hachaklait’ policyholders.

3.2 Analysis of intention to vaccinate

To find the causes for this reduction in vaccination compliance, we distributed 90 questionnaires (Figure 1), based on the TPB model, among Israeli dairy farmers (see detailed description in the methods section). These questionnaires were analysed in a two-stage approach. We first wished to characterize the factors determining the farmers’ intention to vaccinate as a proxy for vaccination behaviour. At the next stage, we aimed to explore which of these factors was both likely to change with time and influence vaccination compliance.

Before the characterization of the factors influencing intention, we wished to test the assumption that in our data the intention to vaccinate represents vaccination behaviour. For this purpose, we used the 56 questionnaires for which we had data on voluntary vaccination (Figure 1, Data-intersect 1). Vaccination among farmers who claimed they are likely to vaccinate was 4.5 times higher (p-value = .007) compared to vaccination among nonintenders (2/18). Analysis of 33 of these farmers for which we had data on future behaviour showed a similar result though only marginally significant (p = .067). Surprisingly, despite this strong association, only 19 out of the 38 (50%) farmers who claimed they are likely to vaccinate indeed vaccinated their herd (Figure 1). The vaccinating farmers showed a stronger belief in the ability of the vaccine to reduce clinical signs of LSD (Table 2). However, the most prominent difference between vaccinating and nonvaccinating farmers was recorded in the indirect measurement of the PBC. Specifically, these farmers were less concerned about the vaccine’s cost and the time and manpower required for vaccination (Table 2).

We next analysed the entire set of 90 questionnaires to identify the factors that determine vaccination intention. Among the background factors, farmers whose herds were located in the centre of Israel and felt lower perceived risk regarding the frequency and consequences of an LSD epidemic showed less intention to vaccinate their herds (Table S2a,b). Furthermore, as expected, higher vaccination intention was associated with both direct and indirect measurements of the three RAA constructs: attitude, subjective norms and perceived behavioural control (Table S3). Among the attitude factors, the highest influence was recorded for the perceptions regarding the benefit from vaccination, reduction of the severity of clinical signs, receiving money from the insurance company, peace of mind and reducing the number of disease cases. Farmers’ intention to vaccinate was significantly influenced by all the nine investigated subjective norm factors. Finally, among the PBC factors, the most influential were the vaccine’s cost and information on the vaccine’s effectiveness (Table S3).

At the following stage, we attempted to determine which of these factors have changed as time elapsed from the LSD epidemic in 2012 and might have caused the reduction in vaccination during 2016–2019. As explained in the ‘Materials and Methods’, since we could not measure the actual change of beliefs during this period we used the comparison between farmers’ answers before and after the 2019 epidemic as a proxy for the farmer’s change of beliefs shortly after the epidemic and long after an epidemic. When comparing these two groups, we found that after the 2019 epidemic, the farmers showed higher intention to vaccinate (Table 3). Furthermore, vaccination norms among farmers who answered the questionnaires before the epidemic in 2019 were significantly lower than the norms among farmers answering the questionnaires after the epidemic (Table 3). Specifically, after the epidemic, the farmers perceived a stronger recommendation for vaccination by the ‘Hachaklait’ and the veterinary services (Table 3). In addition, after the epidemic, the farmers were more concerned about the vaccine’s adverse reactions, although the overall attitude was not significantly different between the two groups (Table 3). These findings suggest a possible connection between a post epidemic change in these specific norms and a change in vaccination intention.

The multivariable linear regression revealed four statistically significant factors associated with farmers intention to vaccinate: the time of questionnaire filling (higher for after the 2019 epidemic), the farm location (lower in the centre of Israel), the farmer’s perceived recommendation to vaccinate by the private vet and the farmer belief that the vaccine will be economically beneficial (Table 4).

4 DISCUSSION

To the best of our knowledge, this is the first study, both in human and veterinary medicine, that investigates the dynamics of vaccination compliance and the factors which influence its deterioration after an epidemic. The results of this study show that vaccination compliance diminishes as time elapses from an epidemic. The main factor
TABLE 2 Comparison of the average direct and indirect measurements of attitude, norms and PBC, between LSD vaccinating and nonvaccinating farmers (in 2019) who showed high intention to vaccinate

| Vaccinating in 2019 | Past and future behaviour | Future behaviour |
|--------------------|---------------------------|-----------------|
|                     | No (N = 19) | Yes (N = 19) | T.test, p value | No (N = 10) | Yes (N = 9) | T.test, p value |
| Direct              |             |             |                |             |             |                |
| Attitude            | 3.11 (1.55) | 3.58 (1.50) | .345           | 3.85 (1.33) | 3.78 (1.56) | .915           |
| Norms               | 3.97 (1.05) | 4.42 (0.85) | .158           | 3.95 (0.90) | 4.78 (0.51) | .026           |
| PBC                 | 4.74 (0.56) | 4.79 (0.42) | .745           | 4.70 (0.67) | 4.78 (0.44) | .773           |
| Indirect            |             |             |                |             |             |                |
| Attitude            | 17.82 (3.86) | 19.20 (3.38) | .247           | 16.93 (3.87) | 20.26 (2.48) | .042           |
| A2 (Reducing the severity of clinical signs) | 17.68 (5.93) | 22.10 (3.03) | .006           | 16.10 (6.21) | 22.22 (2.63) | .014           |
| Norms               | 4.57 (2.87) | 5.44 (2.68) | .344           | 3.90 (2.62) | 5.67 (2.15) | .129           |
| PBC                 | 4.25 (2.56) | 6.16 (2.35) | .022           | 3.95 (2.83) | 6.85 (2.27) | .026           |
| P1 (Vaccine’s cost) | 3.53 (2.82) | 6.37 (3.34) | .007           | 4.30 (3.13) | 6.33 (3.94) | .227           |
| P2 (Time and manpower required) | 1.11 (5.30) | 5.11 (4.27) | .015           | –1.20 (5.01) | 5.78 (4.38) | .005           |

Note: Analysis is presented separately for all farmers for which the behaviour was recorded (N = 38) and only for future behaviour (N = 19) (for the beliefs only significant results (p < .05) are presented).

Abbreviation: PBC, PBC, perceived behavioural control.

TABLE 3 Comparison of the intention to vaccinate and the average direct and indirect measurements of attitude, norms and PBC, between farmers who answered the questionnaire before and during/after the LSD epidemic in 2019

| LSD epidemic in 2019 | Before (N = 57) | During/after (N = 33) | T-test, p value |
|----------------------|-----------------|-----------------------|----------------|
| Intention            | 3.35 (1.47)     | 4.33 (0.82)           | <0.001         |
| Direct               |                 |                       |                |
| Attitude             | 3.44 (1.17)     | 2.98 (1.23)           | 0.085          |
| Norms                | 3.41 (1.32)     | 3.67 (1.06)           | 0.348          |
| PBC                  | 3.89 (1.50)     | 4.36 (1.03)           | 0.114          |
| Indirect             |                 |                       |                |
| Attitude             | 16.70 (4.34)    | 16.46 (4.39)          | 0.806          |
| A3 (The vaccine will not cause adverse reactions) | 14.07 (5.27) | 11.21 (4.99) | 0.013 |
| Norms                | 3.32 (2.63)     | 4.70 (2.95)           | 0.024          |
| N1 (Hachklait)       | 3.61 (5.01)     | 5.97 (4.30)           | 0.026          |
| N3 (Veterinary services) | 5.11 (3.92)    | 6.82 (3.59)           | 0.043          |
| PBC                  | 4.88 (2.63)     | 4.87 (2.18)           | 0.987          |

Abbreviations: LSD, lumpy skin disease, PBC, perceived behavioural control.

influencing compliance deterioration is the reduction of the farmers’ perceived social pressures to vaccinate. This social pressure was attributed to both private (‘Hachklait’) and governmental (the Israeli veterinary services) veterinary organizations. Together with availability of manpower for vaccination and price considerations, these are the major causes of reduction in vaccination compliance. These findings open an opportunity for interventions to mitigate the compliance deterioration of vaccination for epidemic diseases.

Vaccination compliance is a well-studied issue in human medicine (Betsch et al., 2018; Brewer et al., 2017) and recently is being studied also in veterinary medicine (Elbres et al., 2010; Eschle et al., 2020; Gehrig et al., 2019). Like other studies in which the TPB was used to explain and predict behaviour, we found that the three main constructs – attitude, subjective norms and PBC – predicted the intention to vaccinate (Agarwal, 2014; Schmid et al., 2017).

Both in human medicine studies (with a particular focus on Influenza vaccination) and veterinary medicine studies (e.g. vaccination against Bluetongue disease in cattle), the intention and/or behaviour to vaccinate are significantly associated with the attitude of the decision maker towards vaccination (Schmid et al., 2017; Sok et al., 2016).
Similar to the current study, these studies show a significant association of social pressures with intention. The most important normative referent is the physician/veterinarian. In the current study, we further show that the normative referents can be either governmental (Israeli veterinary services) or private veterinarians ('Hachaklait'). At the level of attitudinal beliefs, there are also similarities. In the study of Sok et al. (2015) who surveyed Dutch farmers, it was indicated that the most influential attitudinal beliefs relate to being insured both economically and psychologically from the disease consequences. In our study, the most influential beliefs were related to the economical benefit of the vaccine, reducing the severity of clinical signs, receiving money from the insurance company, having peace of mind and reducing the number of disease cases. However, as opposed to Sok et al. (2018), we have not found a significant association of intention to vaccinate with the relative risk attitude, or the yearly milk quota (another measure of the size of the herd). This might stem from the low variance among the Israeli dairy farmers and herds which did not enable enough power for such a comparison.

The main novel contribution of the current study is to the understanding of vaccination compliance deterioration as time elapses from an epidemic. Given the consequences of LSD epidemics, one would expect that previous experiences with the disease should have been associated with higher compliance. Surprisingly, we did not find such direct association. However, we did find lower vaccination compliance in the Centre of Israel, which was the least affected area during previous LSD epidemics. This may indicate again on the influence of the existing norms in the area on intention to vaccinate. When comparing of farmers’ direct and indirect measurements of attitude, subjective norms and PBC before and after the epidemic of 2019, we found both higher perceived social pressure to vaccinate and higher intention to vaccinate, after the 2019 epidemic compared to before. Interpretation of this result should be performed cautiously, as the situation right after the epidemic in 2019 is not the exact situation in 2016. In 2016, vaccination became voluntary 3 years after the last epidemic. We also lack the exact picture of the actual reduction in perceived social pressures to vaccinate after the epidemic.

According to the TPB, the PBC construct moderates the interaction between the intention and the behaviour (Armitage & Conner, 2001). This is supported by our results, as we found that among farmers who intended to vaccinate, PBC was the main differentiating factor between farmers who vaccinated and those who eventually did not vaccinate. The 50% reduction that we found from intention to behaviour is indeed within the range described before for different behaviours (Sheeran, 2002) but high compared to human vaccination studies (Brewer et al., 2011).

Another important finding in our study is that past vaccination is a reliable and strong predictor of future vaccination. The multivariable analysis on the data of the 566 dairy farms insured by the ‘Hachaklait’ organization indicates that farmers who vaccinated their herd both in 2017 and 2018 were about 120 times more likely to vaccinate also in 2019 than a farmer with no history of vaccination. This finding was independent of any other demographical characteristics. However, this past behaviour itself can be the result of certain attitudinal, normative and control beliefs (Brewer et al., 2017). This finding implies that most of the effort to increase vaccine compliance should be focused on farmers who withdrew from vaccination or never vaccinated their herd against the disease.

The current study suffers from several limitations. One limitation is the small sample size of farmers who answered the TPB questionnaire. These questionnaires were a subset of a larger study in which the behaviour of farmers was studied to four other livestock diseases. Ideally, each farmer would have been surveyed on all five diseases. However, since that would have made the questionnaire exceptionally long, we preferred to ask each farmer randomly about one disease. Another possible limitation is that the study does not follow the same persons over time and thus does not show directly the personal change of farmers’ beliefs. Rather, we interviewed different farmers at different times and compared the answers. It should be noted, however, that interviewing the same persons at different times may create response biases due to the gained experience by the farmers who repeatedly answer the same questionnaires (Wetzel et al., 2016). It would be, however, interesting to perform similar studies using a repeated questioning methodology as well and to compare the results with the results of the current study.

5 | CONCLUSIONS

The results of our study suggest that future strategies to mitigate vaccination compliance deterioration should be focused on encouraging veterinary organizations (both private and governmental) to continue and exert social pressures on the farmers to vaccinate. The success of such a strategy probably depends on the existing trust between the farmers and the veterinarians and the robustness of the veterinary infrastructure. Veterinarians can also be the main agents to educate farmers regarding the vaccine and the disease. We also suggest that identifying and helping farmers who have difficulties, either in manpower allocation or vaccine funding, may increase vaccination compliance. Such strategies should be examined in the future and their effectiveness should be critically evaluated. It is also of interest to examine the change in beliefs of the veterinarians themselves as time elapses from an epidemic of LSD as well as of other infectious diseases.
These will help to maintain high vaccination compliance along time and prevent the recurrence epidemics.

ACKNOWLEDGEMENTS
We are thankful to Gabriel Kenigswald and Bosmat Mesika for assisting in data collection. This research was funded by the Israeli Dairy Board fund. Grant number 705-0078 and by the STEP-GTP (Science Training and Encouraging Peace—Graduate Training Program).

CONFLICT OF INTEREST
The authors declare no conflict of interest.

ETHICAL APPROVAL
The study was reviewed and approved by the committee for studies involving humans, of the faculty of agriculture, food and environment at the Hebrew university of Jerusalem.

DATA AVAILABILITY STATEMENT
Script and data that support the findings of this study are available on request from the corresponding author. The data are not publicly available due to privacy or ethical restrictions.

ORCID
Michal Morgenstern https://orcid.org/0000-0003-4859-9721
Eyal Klement https://orcid.org/0000-0002-2384-2345

REFERENCES
Agarwal, V. (2014). A/H1N1 vaccine intentions in college students: An application of the theory of planned behavior. Journal of American College Health, 62(6), 416–424. https://doi.org/10.1080/07484841.2014.917650
Aizen, I. (1985). From intentions to actions: A theory of planned behavior. In J. Kuhl & J. Beckmann (Eds.), Action control. SSSP Springer series in social psychology. Springer. https://doi.org/10.1007/978-3-642-69746-3_2
Albarracin, D., Johnson, B. T., Fishbein, M., & Muellerleile, P. A. (2001). Theories of reasoned action and planned behavior as models of condom use: A meta-analysis. Psychological Bulletin, 127(1), 142–161. https://doi.org/10.1037/0033-2909.127.1.142
Armitage, C. J., & Conner, M. (2001). Efficacy of the theory of planned behaviour: A meta-analytic review. The British Journal of Social Psychology, 40(Pt 4), 471–499. https://doi.org/10.1348/01446601164939
Bates, D., Maechler, M., Bolker, B., & Walker, S. (2015). Fitting linear mixed effects models using lme4. Journal of Statistical Software, 67(1), 1–48. https://doi.org/10.18637/jss.v067.i01
Ben-Gera, J., Klement, E., Khinich, E., Straum, Y., & Shipigel, N. Y. (2015). Comparison of the efficacy of Neethling lumpy skin disease virus and x10RM65 sheep-pox live attenuated vaccines for the prevention of lumpy skin disease – The results of a randomized controlled field study. Vaccine, 33(38), 4837–4842. https://doi.org/10.1016/j.vaccine.2015.07
Betsch, C., Schmid, P., Heinemeier, D., Korn, L., Holtmann, C., & Böhm, R. (2018). Beyond confidence: Development of a measure assessing the 5C psychological antecedents of vaccination. Plos One, 13(12), e0208601. https://doi.org/10.1371/journal.pone.0208601
Brewer, N. T.; Chapman, G. B.; Rothman, A. J.; Leask, J.; & Kempe, A. (2017). Increasing vaccination: Putting psychological science into action. Psychological Science in the Public Interest: A Journal of the American Psychological Society, 18(3), 149–207. https://doi.org/10.1177/1529100618760521
Brewer, N. T., Gottlieb, S. L., Reiter, P. L., McRee, A. L., Liddon, N., Markowitz, L., & Smith, J. S. (2011). Longitudinal predictors of human papillomavirus vaccine initiation among adolescent girls in a high-risk geographic area. Sexually Transmitted Diseases, 38(3), 197–204. https://doi.org/10.1097/OLQ.0b013e3181f112df
Chapman, G. B., & Coups, E. J. (1999). Predictors of influenza vaccine acceptance among healthy adults. Preventive Medicine, 29(4), 249–262. https://doi.org/10.1016/S0091-7435(99)00147-8
Elbers, A. R., de Koeijer, A. A., Scolmacchia, F., & van Rijn, P. A. (2010). Questionnaire survey about the motives of commercial livestock farmers and hobby holders to vaccinate their animals against Bluetongue virus serotype 8 in 2008-2009 in the Netherlands. Vaccine, 28(13), 2473–2481. https://doi.org/10.1016/j.vaccine.2010.01.047
Eschle, S., Hartmann, K., Rieger, A., Fischer, S., Klima, A., & Bergmann, M. (2020). Canine vaccination in Germany: A survey of owner attitudes and compliance. Plos One, 15(8), e0238371. https://doi.org/10.1371/journal.pone.0238371
European Food Safety Authority (EFSA), (2017). Lumpy skin disease: I. Data collection and analysis. EFSA Journal. European Food Safety Authority, 15(4), e04773. https://doi.org/10.2903/j.efsa.2017.4773
Calistrì, P., DeClercq, K., Gubbins, S., Klement, E., Stegeman, A., Cortíñas Abrahantes, J., Antoniou, S. E., Broglia, A., Gogin, A., & European Food Safety Authority (EFSA). (2019). Lumpy skin disease: III. Data collection and analysis. EFSA Journal. European Food Safety Authority, 17(3), e05638. https://doi.org/10.2903/j.efsa.2019.5638
Francis, J., Eccles, M. P., Johnston, M., Walker, A. E., Grimshaw, J. M., Foy, R., Kaner, E. F. S., Smith, L., & Bonetti, D. (2004). Constructing questionnaires based on the theory of planned behaviour: A manual for health services researchers. Centre for Health Services Research, University of Newcastle upon Tyne.
Gehrig, A. C., Hartmann, K., Günther, F., Klima, A., Habacher, G., & Bergmann, M. (2019). A survey of vaccine history in German cats and owners’ attitudes to vaccination. Journal of Feline Medicine and Surgery, 21(2), 73–83. https://doi.org/10.1177/1098156718795838
Harrell, F. E. Jr., & Dupont, C. (2021). Hmisc: Harrell Miscellaneous. R package version 4.5-0. https://CRAN.R-project.org/package=Hmisc
Hebbali, A. (2020). olsrr: Tools for building OLS regression models. R package version 0.5.3. https://CRAN.R-project.org/package=olsrr
Jozkowksi, K. N., & Geshnizjani, A. (2016). Using a reasoned action approach to examine US college women’s intention to get the HPV vaccine. Health Education Journal, 75(1), 14–26. https://doi.org/10.1177/00247-5
Klement, E., Broglia, A., Antoniou, S. E., Tsiamidis, V., Plevraki, E., Petrovīc, T., Polaček, V., Debeljak, Z., Miteva, A., Alexandrov, T., Marojevic, D., Pite, L., Kondratevko, V., Atanasov, Z., Gubbins, S., Stegeman, A., & Abrahantes, J. C. (2020). Neethling vaccine proved highly effective in controlling lumpy skin disease epidemics in the Balkans. Preventive Veterinary Medicine, 181, 104595. https://doi.org/10.1016/j.prevetmed.2018.12.001
McEachan, R., Taylor, N., Harrison, R., Lawton, R., Gardner, P., & Conner, M. (2016). Meta-analysis of the reasoned action approach (RAA) to understanding health behaviors. Annals of Behavioral Medicine: A Publication of the Society of Behavioral Medicine, 50(4), 592–612. https://doi.org/10.1007/s11085-016-9798-4
Meuwissen, M. P. M., Hinrue, R. B. M., & Hardaker, J. B. (2001). Risk and risk management: An empirical analysis of Dutch livestock farmers. Livestock Production Science, 69, 43–53. https://doi.org/10.1016/S0301-6226(00)00247-5
Ratnapradipa, K. L., Norrenberns, R., Turner, J. A., & Kunerth, A. (2017). Freshman flu vaccination behavior and intention during a nonpandemic season. Health Promotion Practice, 18(5), 662–671. https://doi.org/10.1177/1524839917172731
R Core Team. (2019). R: A language and environment for statistical computing. R Foundation for Statistical Computing. https://www.R-project.org/
Rizopoulos, D. (2006). Itm: An R package for latent variable modelling and item response theory analyses. Journal of Statistical Software, 17(5), 1–25. http://www.jstatsoft.org/v17/i05/
Schmid, P., Rauber, D., Betsch, C., Lidolt, G., & Denker, M. L. (2017). Barriers of influenza vaccination intention and behavior – A systematic review of influenza vaccine hesitancy, 2005–2016. PloS One, 12(1), e0170550. https://doi.org/10.1371/journal.pone.0170550

Sheeran, P. (2002). Intention–Behavior relations: A conceptual and empirical review. European Review of Social Psychology, 12, 1–36.

Sok, J., Borges, J. R., Schmidt, P., & Ajzen, I. (2021). Farmer behaviour as reasoned action: A critical review of research with the theory of planned behaviour. Journal of Agricultural Economics, 72(2), 388–412.

Sok, J., Hogeveen, H., Elbers, A. R. W., & Lansink, A. O. (2015). Farmers’ beliefs and voluntary vaccination schemes: Bluetongue in Dutch dairy cattle. Food Policy, 57, 40–49.

Sok, J., Hogeveen, H., Elbers, A. R., & Oude Lansink, A. G. (2016). Using farmers’ attitude and social pressures to design voluntary Bluetongue vaccination strategies. Preventive Veterinary Medicine, 123, 114–119. https://doi.org/10.1016/j.prevetmed.2016.09.016

Sok, J., Hogeveen, H., Elbers, A. R. W., & Oude Lansink, A. G. J. M. (2018). Perceived risk and personality traits explaining heterogeneity in Dutch dairy farmers’ beliefs about vaccination against Bluetongue. Journal of Risk Research, 21(5), 562–578.

Tuppurainen, E., Dietze, K., Wolff, J., Bergmann, H., Beltran-Alcrudo, D., Fahrion, A., Lamien, C. E., Busch, F., Sauter-Louis, C., Conraths, F. J., De Clercq, K., Hoffmann, B., & Knauf, S. (2021). Vaccines and vaccination against lumpy skin disease. Vaccines, 9(10), 1136. https://doi.org/10.3390/vaccines9101136

Tuppurainen, E. S., & Oura, C. A. (2012). Review: Lumpy skin disease: An emerging threat to Europe, the Middle East and Asia. Transboundary and Emerging Diseases, 59(1), 40–48. https://doi.org/10.1111/j.1865-1682.2011.01242.x

Wetzel, E., Böhneke, J. R., & Brown, A. (2016). Response biases. In F. T. L. Leong, D. Bartram, F. Cheung, K. F. Geisinger, & D. Iliescu (Eds.), The ITC international handbook of testing and assessment (pp. 349–363). Oxford University Press. https://doi.org/10.1093/med.psych/9780199356942.003.0024

Wheelock, A., Thomson, A., & Sevdalis, N. (2013). Social and psychological factors underlying adult vaccination behavior: Lessons from seasonal influenza vaccination in the US and the UK. Expert Review of Vaccines, 12(8), 893–901. https://doi.org/10.1586/14760584.2013.814841

Wickham, H., François, R., Henry, L., & Müller, K. (2020). dplyr: A grammar of data manipulation. R package version 1.0.2. https://CRAN.R-project.org/package=dplyr

SUPPORTING INFORMATION
Additional supporting information can be found online in the Supporting Information section at the end of this article.

How to cite this article: Morgenstern, M., Sok, J., & Klement, E. (2022). Perception of low social pressure and lack of capacity reduces vaccination compliance – The case of lumpy skin disease. Transboundary and Emerging Diseases, 69, e2779–e2788. https://doi.org/10.1111/tbed.14629