Altruism in blood donation: out of sight out of mind?

Closing donation centers influences blood donor lapse

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Abstract

In this paper, we use register data on all blood donors ($n = 259,172$) and changes in geographical locations of blood donation centers in the Netherlands over the past decade, to examine the strength of altruistic motivations in blood donation by testing how blood donor behavior changes after the cost of donating in the form of time and inconvenience increases. We examined whether closing donation centers influences blood donor lapse, and whether the risk for lapse varies between donors with different blood groups. A lower lapsing risk for donors with universal, O-negative blood as costs increase is considered as evidence of altruism: continued efforts in making a societal impact despite the increased time commitment would indicate altruism in donor behavior. In the total sample, 137,172 (52.9%) donors lapsed at least once. We found a very strong effect of changes in the distance to the nearest collection point on donor lapse. Donors whose nearest donation center closed were 53% more likely to lapse than donors whose donation center remained open, with the risk for donor lapse increasing with each extra kilometer distance to the new nearest donation center. While O-negative donors were 10.5% less likely to lapse after closing a donation center compared to donors with other blood groups, the effect of closing was similar across blood groups. Based on these results, we conclude that blood donors are clearly sensitive to cost changes imposed by blood banks and that they are not particularly motivated by altruistic concerns. Future studies are recommended to further examine the role of contextual factors in motivational change across the blood donor career. Blood banks are advised to strategically place donation centers throughout the country to promote blood donations, and design interventions to reduce donation barriers after changing their donation centers' locations.

Keywords

Altruism, blood donation, prosocial behavior, donation center, relocation, travel distance

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Every day, blood transfusions are used to save lives after traumatic events as well as in treatment of serious diseases. To ensure a sufficient supply of blood products, hospitals heavily rely on donors who voluntarily donate blood to help anonymous recipients in the absence of (financial) compensation. For this reason, blood donation is often regarded as archetypal example of altruistic behavior (Titmuss, 1971). Experimental studies on blood donor behavior, however, have shown that blood donation is not exclusively motivated by altruistic concerns for recipients but also driven by self-regarding motivations such as warm glow (Ferguson, Farrell, & Lawrence, 2008; Ferguson, Taylor, Keatley, Flynn, & Lawrence, 2012b). Also, there is evidence that donors are deterred by material costs and the inconvenience of donating (Schreiber, Schlumpf, Glynn, et al., 2006). The geographic location of blood donation centers affects both the costs and inconvenience of donating.

In this paper we study the effects of closure of blood collection centers and changes in travel distance from psychological and economic perspectives on altruism. In psychology, *personal sacrifice* is a key characteristic of the purely altruistic gift (Krebs, 1970; Unger, 1991). We examine the strength of altruistic motivation in blood donation by testing how many donors continue to give blood after the cost of donating in the form of time and inconvenience increases (Schreiber et al., 2006). Donors are more likely to stop donating blood when their available time becomes a scarcer resource and blood donation becomes more costly after childbirth or starting a new job (Piersma, Bekkers, de Kort, & Merz, 2019). Our prediction is that donors in general are more likely to stop giving blood when the costs of donating blood increase because the travel distance to the nearest blood donation center increases. Yet there will be altruistically motivated donors who are prepared to make an additional sacrifice and continue to give blood even if it takes more time.

In economic models of altruism the defining characteristic of a purely altruistic gift is that it helps supply a public good (Ottoni-Wilhelm, 2017; Vesterlund, 2006). An implication of the economic model of altruism is that donors respond to changes in need. When the need for blood increases, altruistic donors should give more. Differences in blood groups among donors create exogenous variation in the need for their blood (Wildman & Hollingsworth, 2009), as the blood group of the donor has to be compatible with that of the patient to prevent transfusion reactions such as blood clotting (Landsteiner, 1961). O-negative donors are an exception to this rule. Their blood can be transfused regardless of the recipient's blood group, making donors with the universal, O-negative blood group more valuable to the blood bank than donors with common blood groups (i.e., A-positive and O-positive, present in 74% of the general population) or less common blood groups (i.e., A-negative, B-positive, B-negative, AB-positive and AB-negative, present in 19% of the general population; Sanquin, 2019b). Our prediction from the economic model of pure altruism is that donors with the more valuable O-negative blood group are less likely to stop donating when the costs increase. To the extent that blood donation is motivated by altruism, O-negative donors should continue donating despite the increased costs, and be willing to sacrifice more, because their blood has a higher public benefit for society (Figure 1). In addition to altruistic concerns for recipients, donors are also motivated by more self-centered motives, such as warm glow concerns for one's social reputation or self-image. When such concerns affect blood donor behavior, its motivation is 'impure' (Andreoni, 1990).

To examine altruism in blood donor behavior, we use register data on all blood donors and blood donation centers in the Netherlands over the past 10 years (Sanquin, 2018). First, we track closings of these donation centers to exploit variation in the costs of blood donation. When the blood bank closes a donation center, the travel time for donors who live close to that center increases. Second, we test to what extent the risk of lapse after the closing of a donation center varies between donors with different blood groups. A lower lapsing risk for donors with O-negative blood is considered as evidence

of altruism: their continued efforts in making a societal impact despite the increased time commitment indicates altruism in donor behavior.

Figure 1 Conceptual model for the hypothesized associations between changes in blood donation center characteristics and blood donor lapse. Black arrows represent positive relationships; the red arrow represents a negative relationship.

By estimating the effects of closing or changing opening days of blood donation centers on individual donor behavior, we examine the role of contextual geographical factors in blood donation. In previous studies, former donors reported to have stopped donating blood because the donation center was too far away or had inconvenient opening times (Klinkenberg, Romeijn, De Kort, & Merz, 2018; Schreiber et al., 2006). As these studies use cross-sectional self-reports of donation motivations, we know very little about the causal effects of contextual factors on blood donor behavior and its influence over time. Yet these insights are of high practical relevance. Blood banks can use them to more efficiently promote blood donations by strategically placing donation centers throughout the country, which is easier than manipulating donors' personal norms and altruistic values (Boenigk, Leipnitz, & Scherhag, 2011).

Blood collection in the Netherlands

Before we state our hypotheses about altruism in blood donation, and the relation between closings of donation centers and donor behavior, we provide some background information on the context of our study. In the Netherlands, blood collection is organized by Sanquin, the monopolist non-profit organization responsible for the collection of whole-blood and plasma throughout the country. Sanquin was founded in 1998 after merging the Central Laboratory for Blood Transfusion Services with the countries' nine independent blood banks, which were part of the Dutch Red Cross. In 2018, approximately 330,000 voluntary blood donors made a total of slightly over 720,000 non-remunerated, anonymous whole-blood and plasma donations (Sanquin, 2019a). Donations can be made at both mobile and fixed locations. Donors are invited to donate blood at a specific location, during a specified two-week walk in period for fixed locations and at a specific date for mobile ones, by offline postcards, with O-negative donors receiving a higher average number of yearly donation invitations compared to donors with other blood groups.

To improve the cost-effectiveness of the blood collection, Sanquin constantly evaluates the geographical locations of its blood donation centers. Over the past decade, this led to a large number of reforms in terms of the number of blood donation centers and their opening times. Partly due to a large reorganization in 2013, merging four regional blood banks into one central blood collection agency, the number of donation centers decreased by 46%, from 252 in 2010 to 136 in 2018 (Figure 2). Our explorative analyses illustrated that decisions to close donation centers were not random, with rural areas – where donors are likely to be more loyal than in urban areas – in the Northern provinces of the Netherlands showing the largest decrease in the number of donation centers. Due to these non-random closings, this paper does not report on a natural field experiment. It is still unknown, however, to what extent the closings have affected blood donor behavior, and whether these effects vary between donors with different blood groups.

Figure 2 Blood donation centers in the Netherlands in 2010 (left) and 2018 (right).

Closing blood donation centers

Looking at studies based on self-reports of blood donor motivations, the location of the donation center is a frequently mentioned reason (not) to donate. Active donors reported that they started donating simply because there was a donation center close by (Charbonneau, Cloutier, & Carrier, 2015; Kuruvatti, Prasad, Williams, Harrison, & Jones, 2011; Schlumpf et al., 2007). Inactive donors reported that they stopped donating because their standard donation center closed down or moved to a less convenient location (Charbonneau, Cloutier, & Carrier, 2016; Godin, Conner, Sheeran, Bélanger-Gravel, & Germain, 2007; Hupfer, Taylor, & Letwin, 2005; Schreiber et al., 2006). In the Netherlands, the presence of a blood collection center in a municipality was shown to be associated with a higher proportion of blood donors within that municipality (Bekkers & Veldhuizen, 2008). In Canada, studies showed that having a blood donation center within a five kilometer radius was positively associated with the number of donors in that area (Saberton, Paez, Newbold, & Heddle, 2009) and the donation frequency of these donors (Cimaroli, Páez, Newbold, & Heddle, 2012).

Practical motivations and barriers to donate blood are likely to be associated with material costs in terms of distance and time. Donors need to have sufficient time to donate blood (Musick & Wilson, 2008). Donors typically walk or bike to the nearest donation location. The time required for a donation increases as the travel time to the nearest donation center increases. Moreover, the chance that donors stop donating increases when their available time becomes a scarcer resource (Piersma et al., 2019; Schreiber et al., 2006). Following this argument, donating blood would become more time consuming, and thus more unlikely, when the distance to the nearest donation center becomes larger. We hypothesize that:

Hypothesis 1: Closing a donation center increases the distance to the donor's nearest donation center, which is positively related to blood donor lapse.

Opening days of blood donation centers

Besides closing a donation center, its opening days also influence blood donor behavior. When opening days of donation centers are reduced, it becomes more difficult for blood donors to plan their donations. In an exit-survey among stopped blood donors in the Netherlands, 26% reported that inconvenient opening times of donation centers were among the main reasons to stop donating (Klinkenberg et al., 2018). Comparable results were found in other contexts and countries (Charbonneau et al., 2016; Osborne, Bradley, & Lloyd-Griffiths, 1978; Schreiber et al., 2006).

These findings may be explained from theories on habit formation, with blood donation becoming semi-automatic behavior over time (Charng, Piliavin, & Callero, 1988). Blood donors accommodate their donations in the rhythm of daily living by rescheduling competing activities to free up a time slot to travel to the donation center and donate blood. Especially for frequent donors it is convenient to pick a fixed day to donate depending on the opening hours of the donation center and the competition for time in their schedules. While it is argued that blood donations are too infrequent and resource-intensive to become automatic behavior (McMahon & Byrne, 2008), donating blood may become part of a routine, especially when donating more frequently and over longer periods of time (Charng et al., 1988). Descriptive statistics from the Dutch blood donor database (Sanquin, 2018) show that most donors indeed seem to have a donation routine. When donors are forced to break their routine, for instance when opening days of the donation centers are changed or reduced, this might negatively affect their donation behavior. We hypothesize that:

Hypothesis 2: Decreasing the number of opening days of a donation center is positively related to blood donor lapse.

Altruism as a motivation of blood donation

In the economic model of pure altruism, blood donations are motivated by public benefits, such as the supply of blood to patients and drug development (Vesterlund, 2006). Because the blood of O-negative donors can be transfused into patients of any blood group, it can be used more efficiently and the public benefits of a donation by an O-negative donor are larger. Previous findings on blood group differences in donation rates are somewhat mixed. Though some studies found no association between blood groups and donation rates, indicating that blood donation is driven by various motivations (Wevers, Wigboldus, De Kort, Van Baaren, & Veldhuizen, 2014; Wildman & Hollingsworth, 2009), others found O-donors to have a higher chance of ever donating (Sasaki, Funasaki, Kurokawa, & Ohtake, 2020), O-negative donors to have a higher chance of returning for a subsequent donation

(Gemelli, Hayman, & Waller, 2017), and being a high-frequency donor (Veldhuizen, Doggen, Atsma, & De Kort, 2009). More specifically, Sasaki and colleagues (2020) found that the positive association between O-blood group and blood donations was especially present when donors knew that their blood could be used to treat all patients in need of blood. Hence, we hypothesize that:

Hypothesis 3a: O-negative donors are less likely to lapse than donors with other blood groups.

Hypothesis 3b: An increased distance to the donor's nearest donation center has a stronger positive relation with blood donor lapse among donors with other blood groups than among donors with the O-negative blood group.

Materials and methods

Data and procedure

To retrieve information on blood donor behavior and donation center characteristics, we used historical information from the Dutch blood donor database between 2010 and 2018 – the years for which complete information was available on blood donors and blood donation centers in the Netherlands (eProgesa; Sanquin, 2018). This large-scale register database contains information on all Dutch whole-blood and plasma donors and individual donation behavior, such as blood group, donation frequency and return rates, as well as donation dates, times and locations. Donors were included in the study sample if they gave their informed consent to use their anonymized donation data for scientific research.

To arrive at the final study sample, individual blood donors were included if the postal code of their home address was known, if they donated at least once between 2010 and 2018, and if donation information of the donor was known to Sanquin for at least two subsequent years in order to be able to track behavioral changes over time. Moreover, donors were included if they were not permanently deferred for future blood donations, if they donated whole-blood instead of plasma (e.g., different transfusion compatibility, and different strategies for plasma donor recruitment and solicitation), if they did not move (i.e., their postal code did not change in order to only include donors for whom the location change was purely the decision of the blood bank), and if they did not live in the two Southern provinces of the Netherlands (i.e., Limburg and Noord-Brabant where no location changes had taken place; Figure 2). The final sample consisted of 259,172 whole-blood donors.

Measures

Blood donor lapse. Blood donor lapse was included in the model as dependent variable. Following the internationally acknowledged definition in European blood donor management (DOMAINE; De Kort & Veldhuizen, 2010), blood donor lapse was defined as a registered donor who made at least one donation but did not donate in the following 24 months. In our analyses, we measured whether or not a donor lapsed in the 24 months after the previous donation (1 = donor lapsed, 0 = donor did not lapse).

Donation center characteristics. We determined for each donor in each year the travel distance from the home address of this donor to the nearest blood donation center in that particular year. Whether or not the nearest donation center closed in a year (1 = donation center closed, 0 = donation center remained open) and the change in its yearly number of opening days were included in the model as independent variables. Changes in the total number of opening days were included as the differences

in opening days between two subsequent years (e.g., a donation center opened for 200 days in 2012 while being open for 150 days in 2013 corresponds to a between-years decrease of 50 opening days).

The distance to the nearest donation center was included in the model as a mediating factor between the closing of a donation center and blood donor lapse, measured as the straight-line distance in kilometers among longitudes and latitudes of blood donors' and donation centers' postal codes (geosphere in R; Hijmans, 2017). Boscoe and colleagues (2012) showed straight-line distances to be highly correlated with travel distances in the United States ($r = .94$), hereby serving as an adequate, easy-to-calculate measure for distance. Changes in the distance to the nearest donation center were included as differences in kilometers between each two subsequent years (e.g., a nearest donation center located at a distance of three kilometers in 2012 while being located at a distance of eight kilometers in 2013 corresponds to a between-years increase of five kilometers).

Behavioral test of altruism. To test for altruism in blood donation, we included the blood group of the donor. Donors were divided in two groups: donors with the universal, O-negative blood group and donors with any other blood group (i.e., O-positive, A-positive, A-negative, B-positive, B-negative, AB-positive, or AB-negative).

Blood donation requests. To estimate the effort that the blood bank may invest in retaining their blood donors, we added the yearly number of blood donation requests to the model. These donation requests include formal invitations from Sanquin by offline postcards and in some cases by telephone. Previous studies reported how receiving a solicitation for blood donation is among the main motivators for donors to donate blood (e.g., Charbonneau et al., 2016; Duboz & Cunéo, 2010), and O-negative donors receive a higher average number of donation invitations. Blood donation requests were measured as the total number of yearly requests in the year the blood donation center closed.

Control variables. To control for correlates of closing of blood donation centers and their changes in opening times at the level of the individual donor, we included information on donor's sex, age, total number of previous blood donations, and total number of yearly deferral days (i.e., characteristics previously shown to be associated with blood donor behaviour Piersma, Bekkers, Klinkenberg, De Kort, & Merz, 2017).

To control for correlates at the level of the municipality, we included information on the population density of the donor's municipality in thousands per square kilometer (i.e., previously shown to be associated with the proportion of blood donors within a municipality; Bekkers & Veldhuizen, 2008). For each year, this information was retrieved from open data of the Dutch Central Bureau of Statistics (CBS) and matched to individual donor records based on the municipality code belonging to their postal code (CBS, 2019). During the study period (2010-2018) no major societal events such as natural disasters or terrorist attacks occurred in the Netherlands that affected the supply of blood.

Statistical analyses

To estimate the associations between changes in donation center characteristics and blood donor lapse we conducted statistical analyses in Stata 15 (College Station, TX: StataCorp LLC). Descriptive analyses were performed on the total study sample to provide an overview of individual blood donor characteristics (e.g., sex, age, donation requests, and blood group prevalence), the occurrence of donor lapse among these donors, and overall blood donation center characteristics in the Netherlands

between 2010 and 2018. To test our hypotheses, we ran random effects probit regression analyses and coarsened exact matching analyses (Blackwell, Iacus, King & Porro, 2009) in Stata 16.1.

In testing our first hypothesis, we examined whether closing the nearest donation center was associated with donor lapse (Table 3, Model I), and whether this association was mediated by an increased distance to the nearest donation center (i.e., ZMediation; Iacobucci, 2012; Table 5.3, Model III). We then obtained predicted probabilities of donor lapse for donors whose nearest location closed or remained open, keeping the other variables in the model at their means. In testing our second hypothesis, we examined whether changing the opening days of a donation center, rather than closing this center, was associated with donor lapse.

Characteristics	All donors (<i>n</i> = 259,172)	O-negative donors (<i>n</i> = 26,618; 10.3%)	Other donors (<i>n</i> = 232,554; 89.7%)
Age	48.1 (± 14.17)	49.5 (± 13.63)	47.9 (± 14.22)
Sex			
Male	108,847 (42.0%)	10,591 (39.8%)	98,256 (42.3%)
Female	150,325 (58.0%)	16,027 (60.2%)	134,298 (57.7%)
Previous blood donations	25.2 (0-485)	28.5 (0-485)	24.8 (0-485)
Blood donor lapse ^b			
in centers that closed	9,321 (15.3%)	913 (13.7%)	8,408 (15.5%)
in centers that remained open	131,186 (10.2%)	12,561 (8.9%)	118,625 (10.4%)
Blood donation requests			
After center closed	2.1 (0-16)	2.7 (0-15)	2.1 (0-16)
After center remained open	2.0 (0-19)	2.6 (0-16)	1.9 (0-19)

^a Data reported as mean ($\pm SD$), mean (range), or number (%). ^b For descriptive statistics on blood donor lapse, each observation in the data is considered to be a unique case, without taking into account the panel data structure.

Table 1 Descriptive statistics of the individual blood donor characteristics from eProgesa, stratified by the donor's blood group^a.

In testing our third set of hypotheses, we examined differences in the lapsing risk of O-negative donors and donors with other blood groups after their nearest donation center closed (Table 4, Model I), and whether this association was mediated by an increased number of donation requests for O-negative donors (i.e., ZMediation; Iacobucci, 2012; Table 5.4, Model II). We then obtained predicted probabilities of donor lapse for O-negative and the other donors, keeping the other variables in the model at their means. In the final models, we added interaction terms between blood group and the distance to the nearest donation center, and between blood group and the number of donation requests to examine whether the increased distance and the increased number of donation requests differently affected the lapsing risk of O-negative and the other donors (Table 4, Model III and Model IV, respectively).

Finally, we estimated matching models to reduce baseline differences between O-negative and donors with other blood types and hence reduce potential biases in the estimated difference between O-negative donors and other blood types. We used Coarsened Exact Matching (CEM; Blackwell, Iacus, King & Porro, 2009) with an automatic binning algorithm to coarsen values of covariates and then exactly match O-negative donors with other blood types to improve balance in covariates. Generally speaking CEM, is superior to other matching methods such as the more commonly known Nearest Neighbor Matching and Propensity Score Matching models because CEM more effectively reduces

imbalance than the other methods (King & Nielsen, 2019). Also, in our data we have both discrete as well as continuous variables with natural breakpoints, for which CEM is the most natural method of matching. A disadvantage of CEM is that it drops observations that cannot be matched exactly, hence lowering the number of observations in the analysis.

Results

Overall blood donor sample

Regarding individual blood donor characteristics, the mean age of the total study sample was 48.1 years ($SD = 14.17$). The sample consisted of 150,325 female blood donors (58.0%), donors had an average number of 25.2 previous blood donations ($SD = 29.53$; range = 0-485), and received an average of 2.1 donation requests per year. Of these donors, 10.3% ($n = 26,618$) had the O-negative blood group and 89.7% ($n = 232,554$) had any of the other blood groups (see Table 1).

The O-negative donors in the study sample were older and more often female compared to the other donors. Moreover, O-negative donors had a higher average number of previous donations (28.5 vs. 25.1 for other donors) and a higher average number of yearly donation requests from the blood bank (2.8 vs. 2.2, respectively).

Characteristics ^b	Donation center remaining open ($n = 1,176$; 92.8%)	Donation center closing ($n = 91$; 7.2%)
Blood donation center		
Distance (before closing)	4.2 (0-24.7)	3.2 (0-21.1)
Distance change	N/A	2.3 (-3.9-10.9)
Opening days (before closing)	116.3 (1-257)	36.9 (1-257)
Opening days change	-2.3 (-144-92)	29.6 (-251-254)
Municipality		
Population density	1,601 (21-6,459)	1,176 (64-5,467)

^a Data reported as mean (range).

Table 2 Descriptive statistics of the blood donation center characteristics from eProgesa, stratified by the donation center status in a year^a.

Between 2010 and 2018, 52.9% ($n = 137,172$) of all blood donors in the sample lapsed at least once. Of these lapsed donors, 11.2% ($n = 15,377$) returned for a donation in the following years (i.e., so-called 'returning donors'). Donor lapse occurred slightly more often among younger donors ($r = -.03$, $p < .001$), and among donors who received a lower number of donation requests and made a lower number of previous donations ($r = -.06$, $p < .001$; $r = -.04$, $p < .001$, respectively). For more information on the bivariate associations, see Appendix 1, which includes Pearson correlations between all study variables.

Blood donation centers in the Netherlands, 2010-2018

Closure of donation centers was not a random event, but occurred more often in less densely populated municipalities in the Northern regions of the Netherlands (see Table 2). A lower population density was associated with closure of donation centers ($r = -.06$, $p < .001$). Thus, we do not have a natural experiment.

The average distance between a blood donor and the nearest donation center in the Netherlands was 4.2 kilometers ($SD = 3.11$; range = 0-24.7) across 2010-2018, with the average distance for all donors having increased over the years (i.e., from 3.8 kilometers in 2010 to 4.3 kilometers in 2018). This distance was smaller in areas where the donation center was going to be closed in the upcoming year compared to areas in which the donation center was going to remain open (3.2 vs. 4.2 kilometers). More than one-fifth of all donors (21.7%; $n = 56,173$) experienced an increase in distance between their home and the next nearest donation center as a result of closing the nearest one. After a closing, the average distance to the nearest donation center increased with 2.3 kilometers ($SD = 2.73$; range = -3.9-10.9), which equals a 72% increased travel distance. While the travel distance increased, donors who experienced a closing were able to donate at a greater number of days per year at the next nearest donation center.

Between 2010 and 2018, blood donation centers in the Netherlands had an average of 113.4 opening days per year ($SD = 98.45$; range = 1-257). For donation centers that remained open in a specific year, the average number of opening days was slightly higher. Moreover, centers that remained open had an average decrease of 2.3 opening days per year ($SD = 15.41$; range = -144-92), showing that donors were confronted with changing donation center characteristics even when the geographical location of their nearest donation center did not change. Below, we discuss the results in testing each of the three hypotheses.

Blood donor lapse after the closing of donation centers

Supporting our first hypothesis, we found that the percentage of lapsed blood donors was much higher in the year after the nearest donation center was closed compared to the percentage of lapsed donors in the year after the donation center remained open (15.3% vs. 10.2%). Moreover, Figure 3 shows how the percentage of lapsed donors after closing the nearest donation center steadily increased with each extra kilometer distance to the new nearest donation center. Of the donors whose nearest donation center closed, 11.6% lapsed when the distance increased by less than one kilometer while 32.8% lapsed when the distance increased by more than nine kilometers.

Probit regression analyses showed that the association between closing of the nearest center and lapse was robust to inclusion of covariates (Table 3, Model I). Donors were 53% more likely to lapse in the years after their nearest donation center closed compared to donors whose donation center remained open (B (95% CI) = .26 (.25, .28), $p < .001$). Moreover, we found positive associations between closing a donation center and an increased distance to the nearest donation center ($\beta = 2.30$, $z = 939.60$, $p < .001$), and between the increased distance and donor lapse (B (95% CI) = .08 (.08, .09), $p < .001$). The increased distance to the nearest donation was shown to be a strong mediator of the relationship between closing a donation center and blood donor lapse ($z = 38.38$, $p < .001$), hereby supporting expectations stated in Hypothesis 1. While a small positive direct effect of closing remains even after controlling for the increased distance, more than 80% of the initial association is mediated by increased distance (Table 3, Model II).

Blood donor lapse after changing opening days of donation centers

In line with expectations from our second hypothesis, the results from the descriptive analysis showed that the percentage of donors who lapsed increased linearly as the number of opening days decreased (up to 15.1% for a decrease of 100 days or more), while the percentage of donors who lapsed decreased linearly as the number of opening days increased (up to 7.9% for an increase of 40 days or more). Probit regression analysis showed that, when the nearest blood donation center remained

open, donors had a higher lapsing risk as the number of opening days decreased (B (95% CI) = -.002 (-.003, -.002), $p < .001$), hereby supporting expectations stated in Hypothesis 2.

Figure 3 Percentage of lapsed blood donors given the distance change in kilometers to the nearest blood donation center, stratified by donation center status and blood group.

Altruism as a motivation of blood donation

Descriptive statistics showed that the overall percentage of lapsed blood donors in the year after the nearest donation center closed was lower among O-negative donors than among other donors (13.7% vs. 15.5%). The percentage of lapsed donors was lower among O-negative donors than among the other donors as the distance to the nearest donation center increased up to 5 kilometers. For an increased distance of more than five kilometers, a more diffused pattern emerged (Figure 3). Furthermore, our results showed that, although the number of donation requests slightly increased in the year after a donation center closed, the number of donation requests for O-negative donors did not increase at a higher rate than the donation requests for other donors: from 2.6 to 2.7 requests for O-negative donors (+3.8%) and from 1.9 to 2.1 requests for other donors (+10.5%).

Variables	Model I			Model II			
	B (SE) ^d	95% CI	p	B (SE)	95% CI	p	Z-value ^e
Closing a donation center	.26 (.01)	.25, .28	< .001	.05 (.01)	.03, .07	< .001	
Distance to a donation center				.08 (.002)	.08, .09	< .001	38.38***

^a Blood donor lapse for non-medical reasons. ^b Results adjusted for donors' sex, age, blood group, total number of yearly deferral days and donation requests, total number of previous blood donations, and the municipalities' population density ($n = 259,149$). ^d Estimated unstandardized regression coefficients. ^e Result for the $Z_{Mediation}$ analysis (Iacobucci, 2012).

*** $p < .001$ ** $p < .01$ * $p < .05$ (two-tailed tests).

Table 3 Results for the random effects probit regression analyses of donor lapse on closing of the nearest donation center, mediated by the increased distance to the nearest donation center^{a,b}.

Variables	Model I			Model II				Model III				Model IV			
	B (SE) ^e	95% CI	p	B (SE)	95% CI	p	Z-value ^f	B (SE)	95% CI	p	Z-value	B (SE)	95% CI	p	Z-value
Distance to a donation center	.09 (.002)	.08, .09	< .001	.08 (.002)	.08, .09	< .001		.08 (.002)	.07, .08	< .001		.08 (.002)	.07, .08	< .001	
O-negative donors	-.08 (.02)	-.12, -.03	< .001	-.04 (.02)	-.08, .004	.074		-.006 (.03)	-.06, .05	.837		-.04 (.04)	-.11, .03	.230	
Donation requests				-.07 (.003)	-.07, -.06	< .001	-13.11***	-.07 (.003)	-.07, -.06	< .001	14.42***	-.07 (.003)	-.07, -.06	< .001	-1.85
Requests * O-negative								-.01 (.008)	-.001, .03	.067		-.01 (.008)	-.03, .002	.097	
Distance * O-negative												.01 (.007)	-.002, .03	.099	

^a Blood donor lapse for non-medical reasons. ^b Donors included in the analysis if their nearest donation center closed ($n = 54,541$). ^c Results adjusted for donors' sex, age, total number of yearly deferral days, total number of previous blood donations, and the municipalities' population density. ^e Estimated unstandardized regression coefficients. ^f Result for the $Z_{Mediation}$ analysis (Iacobucci, 2012).

*** $p < .001$ ** $p < .01$ * $p < .05$ (two-tailed tests).

Table 4 Results of random effects probit regression analyses of donor lapse on the increased distance to a donation center, including the interaction term for O-negative donors^{a-c}

The probit regression model reported in Table 4 (Model I) supported hypothesis 3a: O-negative donors were 10.5% less likely to lapse than donors with other blood groups (B (95% CI) = -.08 (-.12, -.03), $p < .001$). Mediation analyses (Table 4, Model II) showed that this relation could be explained by the higher number of donation requests for O-negative donors ($z = -13.11$, $p < .001$), with a positive association between O-negative donors and the number of donation requests ($\beta = .65$, $z = 17.81$, $p < .001$), and a negative association between the number of donation requests and donor lapse (B (95% CI) = -.07 (-.07, -.06), $p < .001$).

No clear differences were found between O-negative donors and donors with other blood groups in the association between donation requests and donor lapse (B (95% CI) = -.01 (-.001, -.03), $p = .067$). We also found no differences between O-negative donors and donors with other blood groups in the association between the distance to the nearest donation center and donor lapse (B (95% CI) = .01 (-.002, .03), $p = .099$), in contrast with expectations stated in Hypothesis 3b. While O-negative donors were generally less likely to lapse after closing a donation center, this effect was not stronger as the distance to the nearest donation center increased (Table 4, Model IV).

Finally, the three matching analyses among donors for whom the nearest donation location was closed all revealed no difference in lapsing risk between O-negative donors and donors with other blood groups (Table 5). None of the estimates are significantly different from zero. The CEM estimate is somewhat larger than the estimates from the nearest neighbor and propensity score methods, but it is also less precise because the algorithm was able to find exact matches for only one third of all observations. Importantly, the substantive difference between O-negative donors and donors with other blood groups in the CEM analysis was still negligible.

Variables	Nearest Neighbor matching			Propensity Score matching			Coarsened Exact matching		
	B (SE) ^c	95% CI	<i>p</i>	B (SE)	95% CI	<i>p</i>	B (SE) ^d	95% CI	<i>p</i>
O-negative	.002 (.005)	-.008, .013	.689	.006 (.006)	-.005, .018	.292	.006 (.007)	-.007, .020	.362
n		61,050			61,050			20,913	

^a Blood donor lapse for non-medical reasons. ^b Matched on donors' sex, age, blood group, total number of yearly deferral days and donation requests, total number of previous blood donations, and the municipalities' population density.

^c Estimated unstandardized coefficients for the Average Treatment Effect (ATE). ^d Estimated unstandardized coefficients in Linear Probability Model using CEM weights to correct for the imbalance in covariates between o-negative and other blood donors.

*** $p < .001$ ** $p < .01$ * $p < .05$ (two-tailed tests).

Table 5 Treatment effects estimation of O-negative blood group on donor lapse among donors for whom the nearest donation location closed ^{a, b}

Discussion

Using register data on all blood donors and donation centers in the Netherlands over the past decade, we investigated how place matters by tracking closings, travel distances and opening times of these donation centers, creating natural variation in the costs of blood donation. This contextual information was then used to study how donors in the Netherlands respond to increases in the costs of donating, hereby examining economic models of altruism in blood donation. Our results show that blood donors are clearly sensitive to cost. When a blood donation center is closed or when the donation center's yearly number of opening days are decreased, donors are more likely to lapse. Moreover, we find evidence of altruism among blood donors in the Netherlands. Donors with an O-negative blood group

are less likely to lapse than donors with other blood groups because O-negative blood can be used for transfusions to patients with any blood group.

Out of sight out of mind?

In line with previous research, we found that donors in general are more likely to stop donating blood after the costs of donating in the form of time and inconvenience increase. After the nearest donation center closed, blood donors were more likely to stop donating compared to donors whose nearest donation center remained open. For a large part, this effect was explained by the increased travel distance to the nearest donation center. For each additional kilometer of travel distance, the risk for blood donors to lapse steadily increased. These results are in line with studies reporting that donors stop donating because their donation center closed down or moved to a less convenient location (e.g., Charbonneau et al., 2016; Klinkenberg et al., 2018), as well as studies concluding that the risk for donors to lapse increases when donating blood becomes more time consuming (Piersma et al., 2019; Schreiber et al., 2006).

Changing the opening days of donation centers also influenced the donor's donation decision: the percentage of donors who lapsed increased as the number of opening days decreased. These results are in line with previous donor studies concluding that inconvenient opening times of a donation center were among the main reasons to stop donating (e.g., Klinkenberg et al., 2018; Osborne et al., 1978). The effect of changing opening days, however, is relatively small compared to the effect of closing a donation center. While blood donors are likely to have a certain donation routine, their blood donations may indeed be too infrequent to become automatic behavior over time (McMahon & Byrne, 2008).

Impure altruism in blood donation

The evidence supports the economic model of impure altruism. Donors with the universal, O-negative blood group are less likely to lapse compared to donors with other blood groups because they receive more requests to donate blood. This finding is in line with the argument by Gemelli and colleagues (2017), who found a similar association between O-negative donors and their continued donations, and suggested that this could be explained by the higher number of donation requests for these donors instead of their altruistic motivations to supply the public good. Our study indeed showed that the number of donation requests explained why O-negative donors were less likely to lapse, indicating that blood donation is motivated by factors other than pure altruism. In contrast to the prediction from the model of pure altruism, we found no interaction effects between O-negative blood type and the distance to the nearest donation center. While O-negative donors in general are more likely to continue donating blood than blood donors with other blood groups, they are not more willing to make an additional sacrifice as the cost of donating blood increases.

Experimental studies on blood donor behavior showed how blood donations are at least partly driven by self-regarding motivations such as warm glow (Ferguson et al., 2008; Ferguson et al., 2012b), hereby concluding blood donors and their underlying motivations range from other-regarding altruists to self-regarding warm glow givers. We thus might assume O-negative donors to be motivated by an interplay of different forms of altruism, like reluctant altruism (e.g., continuing their blood donations because they feel a moral responsibility to relieve blood shortages) or impure altruism (e.g., continuing their blood donations because they feel more valued as a result of the higher number of donation requests).

Our conclusions on O-negative donors contrast with results from Australia (Wildman & Hollingsworth, 2009), where no association was found between O-negative donors and donation behavior. Perhaps O-negative donors in the Netherlands are more likely to know that their blood can be used more efficiently; this is regularly mentioned in communication and marketing material of the blood bank. Based on the study by Sasaki and colleagues (2020)), we assume knowledge about the use of blood to be of importance in the donation decision: the association between O-negative donors and their continued donations was only present when they knew about the special features of their universal blood. Unfortunately, our data does not contain information about donors' knowledge about the transfusion process. Or perhaps, O-negative donors in the Netherlands receive more informal donation requests at the donation center which makes them feel pressured to continue donating. We were unable to check these assumptions as our data did not include information about informal donation requests to donors with various blood groups.

Strengths and limitations

One of the main strengths of this study is the availability of extensive, longitudinal register data on blood donors and donor behavior, which makes it possible to examine behavioral change across the donor career as a results of blood bank policy decisions. The study findings are highly relevant in evidence-based decision making on blood donor retention by more strategically relocating collection centers throughout the country. Moreover, using the natural variation of donation centers in the Netherlands allows for a theoretical, multidisciplinary discussion on the presence of altruistic motivations in blood donation as well as the broader field of prosocial behavior.

The current study also has some limitations that need to be addressed. First, our research data is limited as the Dutch blood donor database does not contain geographical information about the workplace of the donor. Yet we might assume this location to play a role in the donation decision as having a blood donation center close to the office makes it more convenient for donors to plan their donations right before or after their working hours. Information about closing the nearest donation center to their house address might thus not be relevant for all donors. It is questionable, however, to what extent including this information would have changed the study outcomes. Almost half of all people in the Netherlands work and live in the same municipality, and the average commuting distance is only 20 kilometers (CBS, 2017). Besides, it is reasonable to assume that closing a donation center near the donor's workplace has the same overall effect as shown in the current study.

Second, information on closing the blood donation centers was included on a yearly basis as the register data did not include the centers' exact closing dates. As a result, some donors might have already decided to stop donating blood before the donation center actually closed later that year. For these donors it is unclear whether they stopped donating blood for reasons related to the closing of the donation center (e.g., because they knew the donation center would close later that year and they did not want to plan a subsequent donation at a new location), or because of reasons unrelated to the donation center. Although we believe that, given the large sample size, the inaccurate measure only biased the study outcomes to a small degree, including more precise closing dates of donation centers would allow for more accurate estimations of the true effect sizes.

Future directions for research and blood collection agencies

Despite these limitations, our results have shown how blood bank policy decisions significantly affect blood donor behavior. Future donor studies are recommended to advance the theoretical knowledge

on underlying mechanisms explaining this association, in order to not only understand *when* but also *why* donation decisions change across the blood donor career as a result of contextual changes.

For instance, studies might examine the role of aforementioned variations of altruistic motivations other than pure altruism. Previous studies have shown how such motivations are susceptible to change across the blood donor career, with novice donors more often motivated by reluctant altruism and experienced donors more often motivated by a mix of warm glow and pure altruism (e.g., impure altruism; Ferguson, Atsma, De Kort, & Veldhuizen, 2012a). These motivations thus change with donation experience but might also change when the cost of blood donation changes (e.g., increased time commitment required for a donation). We encourage future research on changes in donor motivation during the blood donor career. Also, it would be worthwhile for experimental studies to design and test interventions targeting donation barriers with the goal to motivate donors who need to make additional time investments to make a subsequent blood donation. For instance, increasing the awareness of the need for blood – an important motivation for people to make a blood donation (Bednall & Bove, 2011) – by increasing the number of donation requests after closing a donation center might convince O-negative donors to continue donating over time.

Our results show that the geographic location of blood donation centers has a very strong effect on blood donor behavior. Given the strong effects of distance, our results are important in further optimizing blood donor recruitment and retention. First, blood banks need to be careful with making changes to the geographic location of donation centers as well as their opening times. While small changes might not harm most donors – increasing the distance with one or two kilometers or decreasing the opening days by 40 days per year has a relatively small impact on donor lapse – their lapsing risk becomes significantly larger as these changes become larger. In any case, timely communication about upcoming changes is important in retaining blood donors. The perceived difficulty for donors to plan a blood donation is likely to increase after any change, even when the new donation center is only a couple of kilometers further away than they were used to. Presenting donors with suitable alternatives for their next donation might be one of the options of in designing interventions to reduce perceived donation barriers associated with new locations and different opening days.

Moreover, it would be worthwhile to test how increasing the number of mobile donation centers while decreasing its opening days affects donor recruitment and retention. Our study has shown that changing opening days has a relatively small effect on donor lapse compared to closing donation centers. Increasing the number of mobile donation centers throughout the country increases the change of having a donation center in the municipality, makes blood donation more visible and more easily accessible, and potentially increases awareness and knowledge about blood donation among (potential) donors. These factors were all previously shown to be associated with a higher likelihood for blood donation. As argued by Boenigk, Leipnitz and Scherhag (2011), promoting blood donations by strategically placing donation centers throughout the country is easier than manipulating donors' altruistic motivations, and experimenting with mobile centers might be effective in increasing the number of blood donations from a more diverse and loyal donor population in the coming years.

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Appendix A

Correlation matrix including Pearson correlations (r) between all study measures

Measures ^a	1	2	3	4	5	6	7	8	9	10	11
1. Blood donor lapse	–										
2. Closing centre	.03***	–									
3. Distance change	.05***	.63***	–								
4. Opening days change	-.01***	.25***	.29***	–							
5. Donation requests	-.06***	-.00**	-.02***	.00	–						
6. O-negative blood group	-.01***	.00	.00	.00*	.08***	–					
7. Other blood groups	.01***	-.00	-.00	-.00*	.09***	-1.00***	–				
8. Previous donations	-.04***	.01***	.01***	-.00**	.20***	.04***	-.01***	–			
9. Age	-.03***	.01***	.01***	.00	.07***	.03***	-.03***	.59***	–		
10. Sex	.00***	-.00*	-.01**	.00	-.13***	.02***	-.02***	-.32***	-.18***	–	
11. Population density	.02***	-.06***	-.06***	-.01***	.03***	-.02***	.00	-.07***	-.15***	.03***	–

^a Measures ordered by category: blood donor lapse (1), donation centre characteristics (2-4), donation requests (5), blood groups (6-7), and control variables (8-11).

*** $p < .001$ ** $p < .01$ * $p < .05$ (two-tailed tests).